REPORT 13

SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMÉLIORATION

DU MILIEU PÉDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

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TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

THE EFFECT OF MOLDBOARD SHAPE ON THE RESIDUE MANAGEMENT POTENTIAL OF THE MOLDBOARD PLOW

FINAL REPORT

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Disclaimer: The views contained herein do not necessarily reflect the views of the Government of Canada or the SWEEP Management Committee.

Executive Summary

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario (1,2). Of the several methods available to control soil erosion and phosphorus movement conservation tillage systems are rated among the best (4). A need exists for conservation tillage system that will maintain crop yield and provide adequate residue cover.

Fall weather conditions in Ontario often prolong harvest and fall primary tillage is done is excessively wet soil. Under these conditions the moldboard plough has been and will likely continue to be the implement of choice for many farmers. The main problem in using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve this performance.

In order to understand and determine the potential for using the moldboard plough as a conservation tillage tool, two approaches were examined. The first included documenting the relative amounts of residue cover obtained after ploughing cereal and grain corn stubble with three commercially available shapes and makes of moldboards. The second approach, incorporated into the same research trial, involved studying the residue management capabilities of different configurations of the modified moldboard plough as first used by Vyn, Daynard and Ketcheson (8,9).

The modified moldboard trial was located on three different sites in Essex county. Site 1 was located on cereal stubble on a clay soil located near Comber, Ontario. Sites 2 and 3 were located on grain corn stubble on clay loam soils near Harrow, Ontario.

The trial was set up as a split-plot design consisting of four replications. The main plot treatments included three of the most popular commercially available shapes and makes of moldboards and moldboard ploughs. The three plough makes selected were Overum, White and John Deere. The subplot treatments consisted of three modifications (cuts) to the moldboard shape and one control (full size moldboard).

Soil surface residue cover data were collected at four different times within the project time frame. They included: before ploughing (fall '88); after ploughing (fall '88); after spring run-off (early spring '89); and after planting (spring and summer '89). Prior to treatment implementation it was found that, in general, Site 2 had 13 percent less residue cover than Sites 1 and 3. All sites had an average residue cover above 80 percent.

In general, the third cut on all three types of ploughs left the greatest amount of residue in fall after the ploughing treatments were implemented in spring, after run-off, at all sites.

As a result of abnormal weather in Essex county in the spring and summer of 1989 the seedbed was prepared twice at Sites 2 and 3. This probably caused some residue to be destroyed, buried or moved out of the plot area, thus influencing the amount of residue left after planting. The amount of soil surface residue left after planting for all sites was well below the Ontario benchmark of 20 percent cover needed for erosion control.

When after planting soil residue cover was measured it was found that on Site 1 the third cut on the moldboards for all three plough makes and the second cut on the White plough left significantly more residue cover. At Site 2 the White first cut treatment and at Site 3 the John Deere second cut treatment left significantly more residue than other treatments.

Moldboard draft was measured using a unit designed and built by the Ontario Centre for Farm Machinery and Food Processing Technology (OCFMFPT) that was mounted between the tractor hitch and the plough. Two load cells measured the pull in the left and right lower links of the tractors 3-point hitch. It should be noted that for each plough make one side of the linkage to the tractor (right hand link for the Overum, left hand link for the White and John Deere) pulled with greater pounds force than the other side of the linkage regardless of the moldboard shape. The magnitude of the difference in pull varied somewhat between moldboard cuts and was not always greater as more cuts were made relative to the pull recorded for full size moldboards.

Volumetric soil moisture content was measured using a device called IRAMS and a Campbell Pacific Nuclea Portaprobe. The moisture content was measured on the day of ploughing (all sites) and the day of planting (Sites 2 and 3). The volumetric soil moisture content on the day of ploughing and the day of planting were quite similar among treatment plots within each site. As a result the potential effect of soil moisture content on other parameters measured was considered equal across all treatments.

The soil surface conditions after ploughing were visually assessed after all ploughing treatments were implemented. The conditions tended to be relatively even and smooth for all moldboard treatments except the third cut treatment across all three sites.

Soybean plant emergence and vegetative growth stage data were collected at the cereal stubble site (Site 1) but heavy rains and crusting experienced in the Essex county may have influenced these site specific results.

After one year of study the following conclusions were made:

1. Soil residue cover left after ploughing and spring run-off tended to increase as a greater portion of the moldboards was removed.
2. Soil surface smoothness after ploughing tended to decline as a greater portion of the moldboards was removed.
3. At a furrow width of 16 inches, maintenance of a 6 inch ploughing depth became more difficult as a greater portion of the moldboards was removed.
4. Although the magnitude of the increase in residue cover left on the soil surface after ploughing with modified moldboards was substantial at two of the three sites, the actual amount of residue cover remaining after ploughing and spring run-off tended to be slightly less or within 20 to 30 percent.
5. For the Overum and John Deere ploughs, the specific draft tended to decline as a greater portion of the moldboards was removed. Specific draft of the White plough tended to increase at the two of three sites.

ABSTRACT

The Effect of Moldboard Shape on the Residue Management Potential of the Moldboard Plough

In 1988-89 three trials were conducted in Essex county in southwestern Ontario to study the effect of moldboard shape on the residue management potential of the moldboard plough. Results from one year of study indicated that in general the third cut treatment left the greatest amount of soil surface residue. The same treatment left the roughest soil surface conditions.

The magnitude of the increase in residue cover left on the soil surface after ploughing with modified moldboards was substantial at two of three sites. The actual amount of residue cover remaining after ploughing and spring run-off tended to be slightly less or within 20 to 30 percent. Specific draft tended to decline for two of three ploughs studied as a greater portion of the moldboards was removed.

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Appendix A: Soil Texture Analyses

Appendix B: Report Submitted by the Ontario Centre for Farm Machinery and Food Processing Technology

1.0 INTRODUCTION AND OBJECTIVES

The erosion of agricultural land and the associated pollution of Lake Erie with sediment and phosphorus have been identified as major agronomic and environmental problems in Ontario[1,2]. At the same time Ontario agricultural producers are striving to reduce the cost of production to leave as wide a profit margin as possible. They are motivated by an economic outlook that generally forecasts over-supply and low prices for agricultural commodities[3]. With these perspectives in mind it is apparent that those techniques that control soil erosion and phosphorus pollution but cost little to adopt, are of particular importance to Ontario's producers.

Of the several methods available to control soil erosion and phosphorus movement, conservation tillage systems are rated among the best[4]. In the United States where soil erosion by water is the main concern, conservation tillage is defined as "any tillage and planting system that maintains at least 30 percent of the soil surface covered by residue after planting"[5]. In Ontario the benchmark figure of 20 percent residue cover of the soil surface is often used in the definition of a conservation tillage system. This is based on the recommendations of researcher T. Vyn, at the University of Guelph[5].

The crop residue left on the soil surface intercepts and dissipates the erosive actions of water and wind. Many conservation tillage systems leave more than the required 20 to 30 percent residue after planting cover and are cost-effective in the long term. However, in the wide spectrum of situations where conservation tillage should be used, there are still some technological gaps and economic drawbacks.

A need exists in Ontario for a conservation tillage system that will maintain crop yield and provide adequate residue cover especially as the clay content of the soil increases and as the drainage capabilities of the soil decline. On a soil texture basis such a system would be of special importance to a large portion of Ontario's Class 1 to 4 land. From a crop production standpoint 25 percent of Ontario's agricultural land is used to produce grain corn. Fall weather conditions often prolong harvest (as in 1985 and 1986) and fall

primary tillage is done in excessively wet soil. Under these conditions the moldboard plough has been, and will likely continue to be, the implement of choice for many farmers. Chisel ploughs and discs do not perform well in these soil texture and moisture conditions. No till and ridge tillage systems, while viable options, will probably only be successful with very good and excellent crop managers.

The main problem with using the moldboard plough is that the implement tends to bury almost all residue from the previous crop. As a result the potential for controlling soil erosion is considered poor. Little work has been done to improve on this performance. If the residue management capabilities of the moldboard plough could be increased to an acceptable level with little or no interference of the lifting and shattering action, then a very large gap in conservation tillage technology would be filled.

With regard to economics, surveys have shown that most farmers now own a moldboard plough[6,7]. As a result a major portion of the extra capital cost often required for the purchase of additional machinery or for planter modifications as a new tillage system is phased in and an old system is phased out, could be eliminated.

In order to understand and determine the potential for using the moldboard plough as a conservation tillage tool, two approaches were examined. The first included documenting the relative amounts of residue cover obtained after ploughing cereal and grain corn stubble with three commercially available shapes and makes of moldboards. The second approach, incorporated into the same research trial, involved studying the residue management capabilities of different configurations of the modified moldboard plough as first used by Vyn, Daynard and Ketcheson[8,9]. To understand the merits of the above study, it is important to consider the previous work of these researchers on this topic and its ramifications for the Ontario farmer.

The Modified Moldboard Plough

Since 1980, tillage research conducted by Vyn, Daynard and Ketcheson at the University of Guelph has studied the effect of various primary tillage tools on grain corn yields and soil surface residue cover. Corn was grown continuously on a silt loam and clay loam soil. The results of these studies are found in Tables 1 and 2. Of particular interest are the results obtained using the modified moldboard plough treatment. These could have a far-reaching effect on Ontario's conservation tillage options, especially in grain corn systems.

The modified moldboard treatment involved the use of a moldboard plough where 70 percent of the actual moldboard part of each plough bottom was removed. No adjustments were made to the share, shin or landside leaving the integral parts of the plough bottom intact. With regard to the effect of the modified moldboard plough treatment on grain corn yield, the data indicate that this treatment was the only one out of five tillage treatments to produce grain corn yields similar to those produced after normal moldboard ploughing on both soil types. The same tillage treatment left three times as much residue cover on the soil surface as the conventional moldboard plough. The results approached the benchmark requirement of 20 percent soil residue cover left after planting for soil erosion control. Visual assessments under field conditions in Huron County using a similarly modified plough indicate that residue covers of greater than 20 percent are attainable.

Using the moldboard plough system, a farmer can increase his residue management potential while still maintaining his crop yield. The expected cost of changing over to this system from a conventional moldboard plough system would be minimal. Currently, used plough bottoms and moldboards are sold for scrap metal value at best. Some are simply discarded or left lying around the farm buildings. These used parts could be recycled into a modified plough system. Most farmers have their own cutting torch or access to a local welding shop. As a result, they could remove the major portion of the moldboard and use the plough bottoms in a modified moldboard plough system.

TABLE 1: EFFECT OF VARIOUS PRIMARY TILLAGE TOOLS ON SURFACE RESIDUE COVER IN SPRING FOR CONTINUOUS CORN PRODUCTION ON TWO SOIL TYPES (AVERAGE OF 1981-84).

PRIMARY TILLAGE	SURFACE RESIDUE COVER (%)			
	SILT LOAM		CLAY LOAM	
	Pre-Plant	Post Plant	Pre-Plant	Post Plant
Moldboard plough	7	4	7	5
Modified moldboard plough	21	14	20	14
Wide-sweep plough	39	20	37	18
Disk-chisel plough	30	20	25	14
Modified disk-chisel plough	26	19	19	12
Zero tillage	62	47	56	49
S.E. (difference)	1.8	1.6	1.7	1.6

TABLE 2: EFFECT OF VARIOUS PRIMARY TILLAGE TOOLS ON GRAIN YIELDS OF CORN GROWN ON TWO SOIL TYPES (AVERAGE OF 1980-84).

PRIMARY TILLAGE	GRAIN YIELD (t/ha)	
	SILT LOAM	CLAY LOAM
Moldboard plough	6.86	7.05
Modified moldboard plough	6.58	6.93
Wide-sweep plough	6.37	6.72
Disk-chisel plough	6.45	6.53
Modified disk-chisel plough	6.49	6.87
Zero tillage	6.12	6.36
S.E. (difference)	0.198	0.253

Adapted from Vyn, T.J., and T.B. Daynard. 1985. Feasibility of Various Primary Tillage Implements for Maize Production in Ontario. University of Guelph; Guelph, Ontario.

With the above points in mind, two questions remain before the system can be broadly promoted. When the major portions of the moldboard parts of the plough bottoms are removed, the draft of the plough is altered. As a result the implement does not pull properly behind the tractor. Since no engineering studies have been done on this system to date, the problem may be quickly solved through experimentation with various shapes and/or combinations of cut-off moldboards. At the same time the effect on the amount of soil residue cover remaining after tillage could be documented. With this information and the data from the University of Guelph, recommendations on the use of a modified moldboard plough system could be developed within one to two years.

The information gathered from the above study could help in allowing the moldboard plough to fill an important gap in current conservation tillage technology in Ontario and possibly North America.

If the moldboard plough can be used successfully in a conservation tillage system many more farmers will seriously consider the conservation option. Once a producer makes the first step toward residue management the chances of his continued commitment to the idea increase substantially.

The effect of plough make and moldboard shape on cereal and grain corn soil surface residue cover

Objectives

i) To determine the effect of modifying the shape of the moldboards on a moldboard plough on the amount of cereal and/or grain corn residue cover left on the soil surface at various times in the growing season.

ii) To prepare preliminary recommendations on the adjustments and specifications for modifying moldboards and moldboard ploughs for optimizing residue management potential.

2.0 DEVIATIONS FROM WORK PLAN

The Ontario Centre for Farm Machinery and Food Processing Technology (OCFMFPT) was requested to characterize and determine the most popular shapes and makes of moldboards and moldboard ploughs in Ontario. After conducting this review it was apparent that five or six makes of plough were most common in Ontario. In looking further at the actual shapes of moldboards in current use and those that were likely to gain in popularity, it was determined that most ploughs regardless of make, were probably fitted with one of three general shapes of moldboards. As a result, it was recommended that for the purposes of this study it would be most efficient and just as effective to use three makes of ploughs fitted with three types of moldboards. In the original proposal the plan was to use five ploughs in Study A to determine the residue management capabilities of popular ploughs in Ontario. From these five ploughs, three, four or five ploughs would be chosen to be included in Study B. Since only three ploughs were chosen in the first place and Study B already called for a treatment using the full moldboard as a control (therefore making possible a statistical comparison of the full moldboards as would have been done in Study A) the need for Study A no longer existed.

A request to drop this study was granted. As a result additional effort was undertaken to document the changes in draft relating to degree of moldboard modification. A video tape of treatment application was also made and soil surface residue counts were taken in the fall after the treatments were applied. Soil moisture content at planting, soybean plant emergence and early season plant vegetative stage were also documented as weather permitted.

The soil moisture content at planting at the cereal stubble site (Site 1) located near Comber, Ontario was not taken due to a lack of time between notification of planting and the occurrence of heavy rains. At the two grain corn stubble sites (Sites 2 and 3) located near Harrow, Ontario, soybean plant emergence and vegetative growth stage were not taken again due to heavy rains and extreme flooding.

All changes noted above were discussed with the client.

With regard to site selection all three sites were located on clay type soils. With greater than 40.0% clay content, Site 1 was classified as a clay textured soil. The intent was to have two different soil textures for each of the grain corn stubble sites but laboratory analyses of soil samples after trial implementation indicated that both sites were classed as clay loam soil. It should be noted however that the soil clay content was 7.2 percent greater at Site 2 when compared to Site 3. The results of soil texture analyses are listed in Appendix A. In addition Site 2 was not tile drained, as was Site 3, and the level of residue left on the soil surface after harvest was approximately 13 percent less than that measured at Site 3.

3.0 MATERIALS AND METHODS

3.1 Location and Site Specifications

The modified moldboard trials were located on three different sites. The first site was on cereal stubble on a clay soil located on Lot 2, Concession 10, Tilbury West Township, Essex County. The two remaining sites were located on grain corn stubble on clay loam soils. These two sites were located on Lots 7 and 8, Concession 4, South Colchester Township, Essex County.

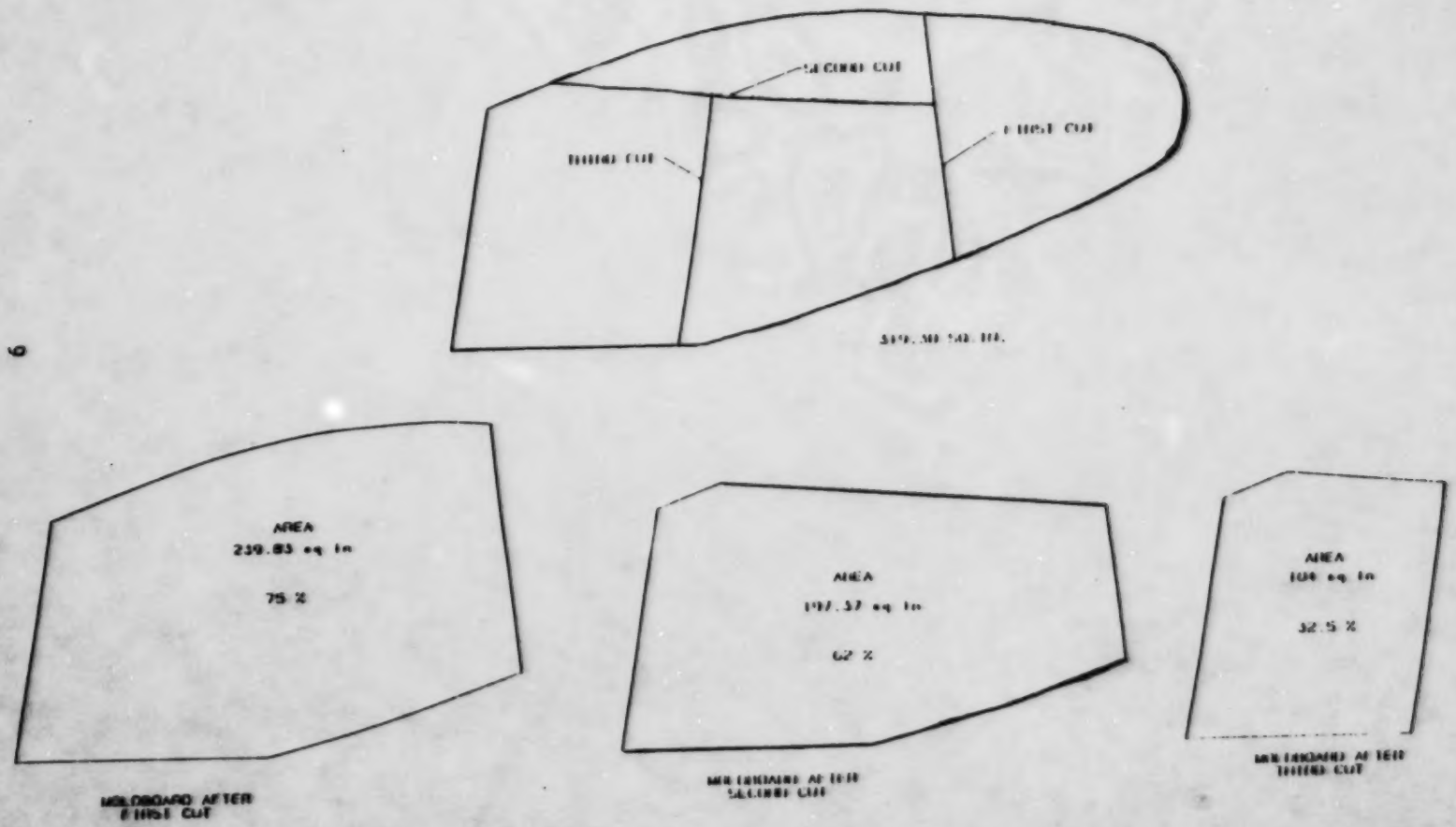
3.2 Experimental Design and Analysis

The trials were set up as a split-plot design consisting of four replications. The dimensions of each plot were 6.1 m wide by 15.2 m long. The main plot treatments included three of the most popular commercially available shapes and makes of moldboards and moldboard ploughs (as determined by the OCFMFPT). The three plough makes selected for the trial were Overum, White and John Deere. Each plough was fitted with moldboards commonly used with that make of plough as listed below:

	PLOUGH MAKE		
	OVERUM (Triple OK)	**WHITE (Cockshutt 508)**	**JOHN DEERE (F1350-F1450)**
Number of bottoms	5	5	5
Moldboard part number	6-6158060490	10-0L-619-16	10-NU 1036
Moldboard type	V-body, European	General purpose	High speed

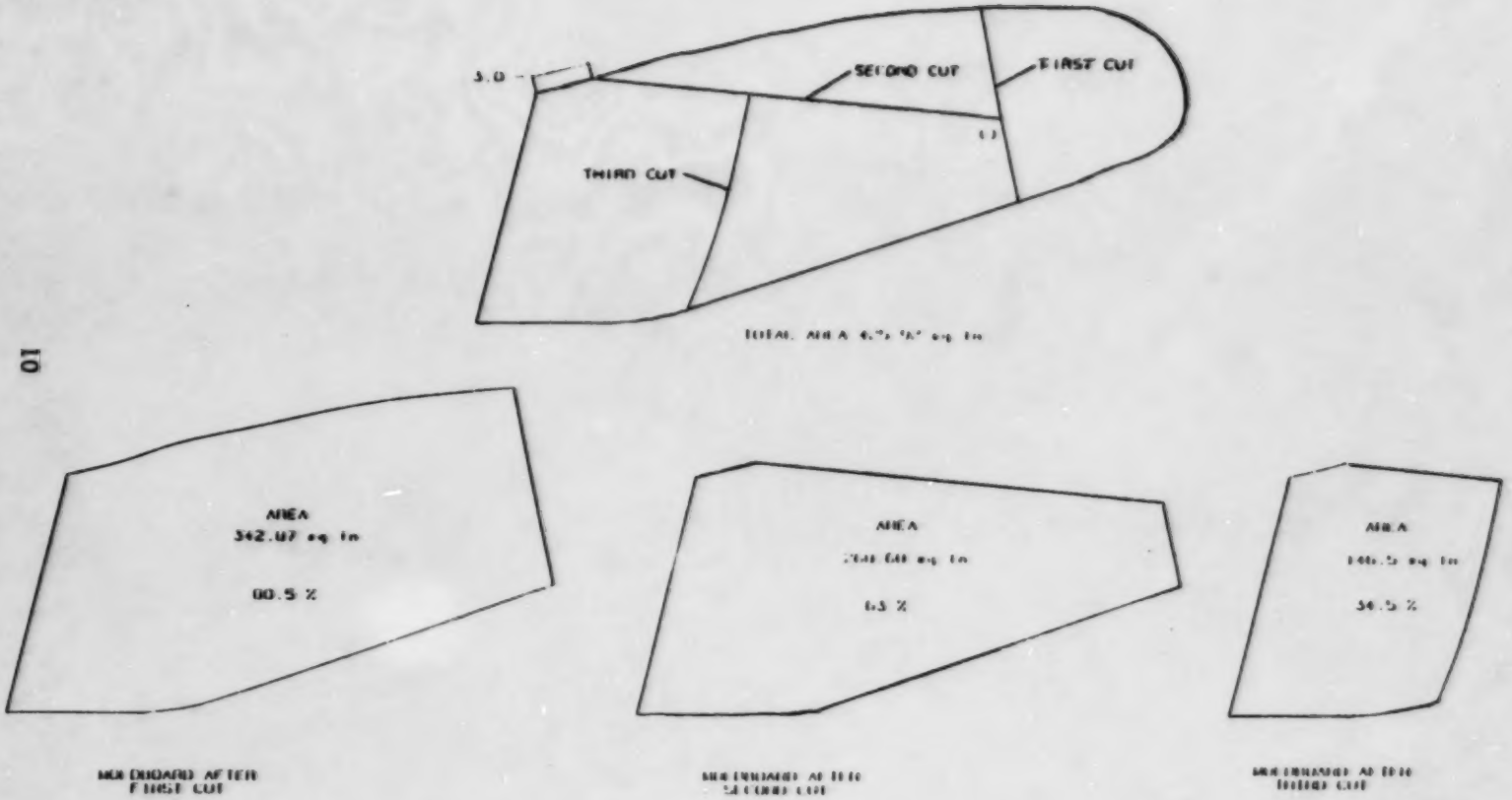
The sub-plot treatments consisted of three modifications (cuts) to moldboard shape and one control (full size moldboard). Figures 1-3 illustrate the different moldboards used as well as the different cuts made.

Figure 1:



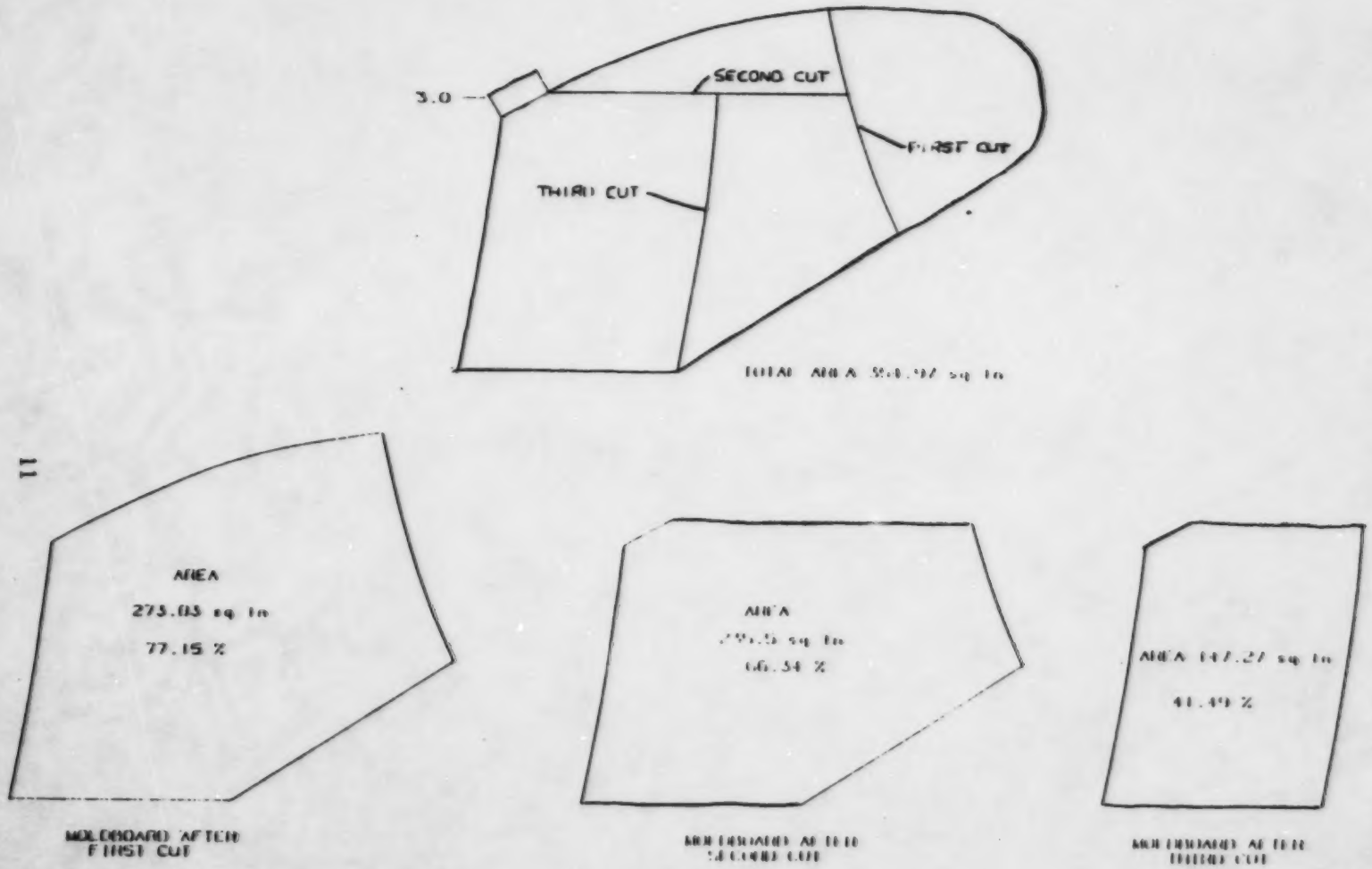
WHITE PLOW (MOLDBOARD)

Figure 2:



OVERRUN FLOW MOLDBOARD (GENERAL PURPOSE)

Figure 3:



JOHN DEERE PLOW MOLOBOARD (HIGH SPEED)

The data were analyzed using an analysis of variance for a randomized complete block design, two factor factorial with one split, at the 0.05 level of significance. In this report locations were analyzed individually due to differences in residue cover, soil texture and soil drainage between sites.

3.3 Agronomic Practices

3.3.1 Cereal Stubble Site (Site 1)

In September, 1988, CMS initiated the modified moldboard study in a field of winter wheat stubble.

On May 24, 1989, mixed varieties of soybeans were planted by the cooperator at 95.2 kg/ha using a grain drill set at 6 inch row spacings. The seedbed was prepared by making two passes with a cultivator.

3.3.2 Grain Corn Stubble Sites (Sites 2 and 3)

In November 1988, CMS conducted two similar modified moldboard studies on grain corn stubble.

Rain delayed planting in the spring. Soybeans (var. KG92) were planted on June 26, 1989 and June 30, 1989 on Sites 2 and 3, respectively. Site 2 was planted at 100.8 kg/ha using an International 510 grain drill set at 7 inch row spacings. Site 3 was planted at 80.6 kg/ha using an International 56 six row plate planter set at 30 inch row spacings. The final seedbed was prepared by making two passes with a disc, one pass with a cultivator, and one final pass with a disc which had harrows and packers attached.

3.4 Measurements

3.4.1 Soil Surface Residue Cover

A rope with 50 knots at 15 cm intervals was used to make four counts of soil residue cover per plot. Residue cover was determined by counting each knot on the rope that

touched a piece of residue. The knotted rope was positioned diagonally across the plot. Two counts were taken from the top right to bottom left corners and two from the top left to the bottom right corners. Data were adjusted to percent residue cover using the following equation:

$$R(\%) = \left[\frac{\sum_{j=1}^{4} Cj}{4} \right] x \quad 100$$

R = mean soil residue cover/plot
C = no. of rope knots touching a piece of residue/50 knots
j = individual values of C

Soil surface residue cover data were collected at four different times within the project time frame. These included:

after harvest (Fall '88);

after ploughing (Fall '88);

after spring run-off (early Spring '89);

after planting (Spring and Summer '89).

3.4.2 Moldboard Plough Draft

A draft measuring unit (Figure 1, OCFMFPT Report, Appendix B), designed and built by the OCFMFPT was mounted between the tractor hitch and the plough. Two load cells measured the pull in the left and right lower links of the tractor's 3-point hitch. The load cell output was displayed on two digital display units and the readings were recorded for each pass by the staff from OCFMFPT. To calculate specific draft, depth of ploughing per plot was also recorded.

Specific draft was determined using the following equation:

$$D_{specific}\ (lbf/in^2) = \frac{D_{total}\ (lbf)}{C\ (in.) \times W\ (in.)}$$

$D_{specific}$ = specific draft
D_{total} = total draft
C = depth of cut in soil
W = width of cut in soil (i.e. total plough width)

By definition 'pull' on an implement is the total force exerted upon the implement by a power unit (i.e. tractor). 'Draft' is the horizontal component of pull and is parallel to the line of motion ... 'Specific draft' is the draft per unit area of tilled cross-section usually expressed as newtons per square centimetre or pounds force per square inch[10]. In this report measurements reported as specific draft allow comparison between moldboard ploughs of different make and moldboard shape. Measurements reported as draft pertain to the moldboard plough with which they are associated. Comparative observations from these latter data are only valid for different moldboard cuts using the same make of moldboard plough.

3.4.3 Soil Moisture Content

In the fall of 1988, volumetric soil moisture content was measured at the cereal stubble clay site using a device called IRAMS. Measurements made were based on time domain reflectometry.

The IRAMS was again used to measure volumetric soil moisture at the grain corn stubble sites in the fall of 1988. In the spring of 1989, a Campbell Pacific Nuclea Portaprobe was used to collect data from the sites. The gravimetric soil moisture content data collected using this instrument were converted to volumetric soil moisture content using the following equation:

$$M_{vol}\ (\%) = M_{grav} \times \text{Dry B.D.}$$

$$= \frac{W_{water}\ (kg)}{W_{water} + W_{soil}\ (kg)} \times \frac{\text{Dry B.D.}_{soil}\ (g/cm^3)}{B.D._{water}\ (g/cm^3)} \times 100$$

M_{vol} = volumetric soil moisture content
M_{grav} = gravimetric soil moisture content
B.D. = bulk density
W = weight

3.4.4 Soil Surface Smoothness

The soil surface of each plot was visually assessed after ploughing was complete. Ratings were given from 0 to 9 where 0 equalled a poor rating (rough, uneven surface) and 9 equalled an excellent rating (even, smooth surface).

3.4.5 Soybean Plant Emergence

The number of plants emerged per square meter were counted at three locations within each plot. These data were collected approximately three to four weeks after the planting date.

3.4.6 Soybean Plant Vegetative Growth Stage

The soybean plant vegetative growth stage[11] was recorded per plant within a square meter of each plot approximately three to four weeks after the planting date. The growth data collected at the cereal stubble clay site were based on the following:

(V) 1 = true leaves showing
(V) 2 = true leaves plus 1st trifoliate
(V) 3 = true leaves plus 1st and 2nd trifoliate
(V) 4 = true leaves plus 1st, 2nd, and 3rd trifoliate

The trifoliate leaves were counted if showing, but they were not necessarily open.

4.0 RESULTS AND DISCUSSION

The results of the modified moldboard study are found on the following pages and in Appendix B.

4.1 Plough Adjustments and Moldboard Modifications

At each site the moldboard ploughs were adjusted to leave maximum soil surface residue cover. During this procedure the following comments and conditions were noted:

1. Overum plough
   - adjusted to cut 16 inch furrow width
   - trashboards removed
   - plough levelled first
   - cut of first furrow required adjustment
   - depth of ploughing was adjusted last
   - adjustments did not appear to have a significant effect on residue left on surface

2. White plough
   - adjusted to cut 16 inch furrow width
   - there was a visual difference in amount of residue left on surface as speed and depth of ploughing varied
   - speed of tractor (FORD TW-15) was set at 4.5 mph/2000 rpm
   - as depth decreased to 5 inch it was difficult to keep the plough in the ground

3. John Deere plough
   - comments were similar to those for other ploughs
   - to decrease plough depth a longer set screw was required

The moldboards were modified as shown earlier in Figures 1-3.

As the cuts were made to the moldboards the following comments regarding use of the ploughs were recorded:

Overum Plough:	no cut	- no problems
	1st cut	- no problems
	2nd cut	- no problems
	3rd cut	- no problems
		- did not have to adjust depth; felt that longer points helped to keep the plough in the ground
White Plough:	no cut	- no problems
	1st cut	- no problems
	2nd cut	- no problems
	3rd cut	- needed to adjust to plough deeper in order to keep the plough in the ground
John Deere Plough:	no cut	- no problems
	1st cut	- no problems
	2nd cut	- no problems
	3rd cut	- needed to adjust to plough deeper in order to keep the plough in the ground
		- last furrow soil slumped back into furrow and plough furrow - wheel compacted soil; rough soil surface resulted

As indicated above, maintaining a uniform plough depth (4-6 inchs is deemed adequate for plant growth) was a problem with two of the three ploughs after the third cut was made to the moldboards. It was noted at Site 3 that at an 8 inch depth of ploughing after the second cut, the White plough turned the soil furrows on end. As a result 'rows' of corn stubble residue were left on or near the soil surface. It was felt that a good ploughing job was done and a desirable level and orientation of residue was achieved.

At a 6 inch depth of ploughing however the furrows appeared to 'flip' over and bury more of the residue. A good ploughing job was done but less residue was left exposed.

The general rule of thumb for moldboard plough adjustment is to plough at a depth equal to half the width of the furrow. This rule applied in the above situation would indicate that there may have been merit in ploughing somewhat deeper than the suggested 6 inch depth in order to achieve maximum soil surface residue cover and a vertical orientation of corn residue.

A greater depth would also have assisted in plough adjustment as the severity of the moldboard cut increased.

4.2 Soil Surface Residue Cover

Prior to treatment implementation, soil residue cover was measured. It was found that in general, Site 1 with cereal stubble residues and Site 3 with grain corn stubble residues had the same amount of cover with levels ranging from 92 to 96 percent and 93 to 97 percent, respectively (Tables 3 and 5). Site 2 with grain corn stubble residues had initial levels of soil residue cover between 79 and 85 percent (Table 4).

In general, after ploughing treatments were implemented at Sites 1, 2 and 3 the third cut on all three types of ploughs left the greatest amount of residue on the soil surface. The White and John Deere third cut treatments left significantly more residue (19 and 17 percent respectively) than any other treatments on Site 1 (cereal stubble). On Site 3 where initial residue cover was higher and soil clay content lower than at Site 2, the Overum third cut and the John Deere and White second and third cut treatments left significantly more residue cover than remaining treatments. The Overum third cut and all of the John Deere treatments left significantly greater amounts of residue cover than other treatments on Site 2 (grain corn stubble).

In April, after spring run-off, it was found that in general, soil residue levels were greatest on the plots ploughed with the third cut treatment at all sites. At Site 1 the John Deere second and third cut and the White third cut treatments left more residue (19%, 21% and 20%) than other treatments. The Overum third cut treatment left significantly more residue on both Sites 2 and with levels of 10 and 33 percent, respectively. The White third cut treatment at Site 3 also left a relatively high residue cover of 30 percent.

Table 3: Cereal Stubble Soil Surface Residue Cover on Clay Soil (Site 1) Modified Moldboard Study, Essex County, 1988-89

Treatment	Residue Cover (%)			
Plough Make/Moldboard Cut	Before Ploughing	After Ploughing	After Spring Run-off	After Planting
Overum no cut	96	3	6	4
Overum 1st cut	96	3	7	5
Overum 2nd cut	96	6	10	6
Overum 3rd cut	92	9	16	10
John Deere no cut	95	8	10	6
John Deere 1st cut	94	6	12	3
John Deere 2nd cut	95	9	19	6
John Deere 3rd cut	95	17	21	12
White no cut	93	5	10	3
White 1st cut	93	9	11	4
White 2nd cut	96	13	13	10
White 3rd cut	93	19	20	10
LSD*	5.5	4.9	4.7	2.6
c.v.	4.0%	38.2%	25.2%	28.7%

*p=0.05

Table 4: Grain Corn Stubble Soil Surface Residue Cover on Clay Loam Soil (Site 2), Modified Moldboard Study, Essex County, 1988-89

Treatment Plough Make/Moldboard Cut	Residue Cover (%) Before Ploughing	After Ploughing	After Spring Run-off	After Planting
Overum no cut	80	4	3	1
Overum 1st cut	81	4	5	1
Overum 2nd cut	83	5	5	2
Overum 3rd cut	83	8	10	1
John Deere no cut	79	6	4	2
John Deere 1st cut	81	6	7	2
John Deere 2nd cut	81	6	6	1
John Deere 3rd cut	85	8	7	2
White no cut	83	5	7	3
White 1st cut	80	4	7	4
White 2nd cut	81	4	5	2
White 3rd cut	83	5	7	2
LSD*	6.0	3.0	3.3	1.4
c.v.	5.0%	36.8%	37.4%	47.8%

*p=0.05

Table 5: Grain Corn Stubble Soil Surface Residue Cover on Clay Loam Soil (Site 3), Modified Moldboard Study, Essex County, 1988-89

Treatment	Residue Cover (%)			
Plough Make/Moldboard Cut	Before Ploughing	After Ploughing	After Spring Run-off	After Planting
Overum no cut	97	24	21	2
Overum 1st cut	94	23	19	2
Overum 2nd cut	94	23	21	2
Overum 3rd cut	97	37	33	2
John Deere no cut	95	20	14	2
John Deere 1st cut	93	22	19	3
John Deere 2nd cut	95	27	19	4
John Deere 3rd cut	96	36	30	3
White no cut	93	16	15	3
White 1st cut	93	22	19	2
White 2nd cut	95	27	20	1
White 3rd cut	95	28	25	2
LSD*	3.7	10.3	8.6	1.3
c.v.	2.7%	27.8%	28.1%	40.5%

*p=0.05

This did not occur, however, at Site 2 where all White treatments were similar for residue cover.

It may be noted that at Site 1 the level of cereal stubble soil residue cover increased between fall ploughing and spring run-off. Precipitation over winter could be expected to move loose soil that initially covered the cereal residue at ploughing and through time expose the residue for measurement in the spring. Residue decomposition and movement within the field by surface water run-off may also have affected the magnitude of the difference.

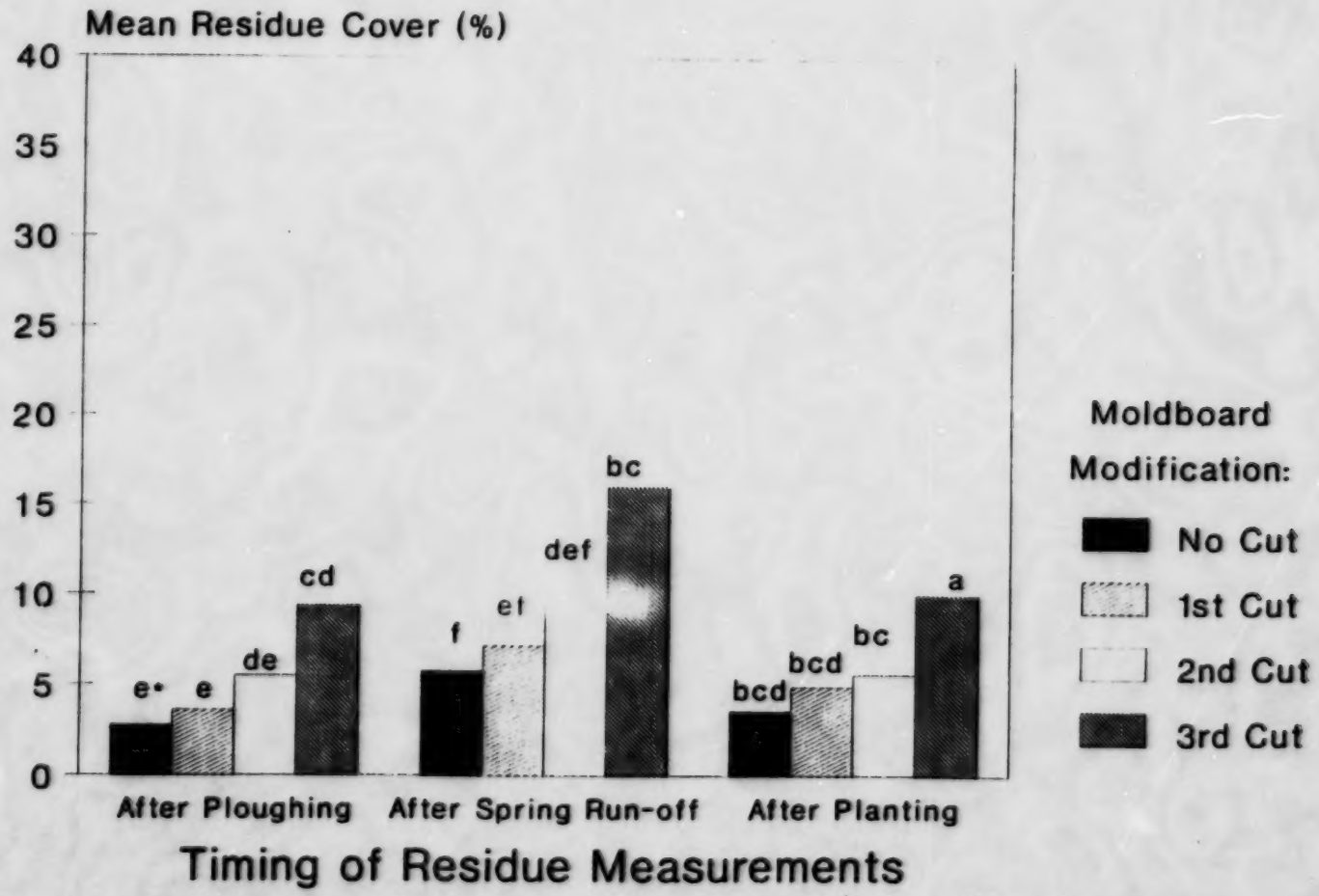
The above trend in fall versus spring residue cover however was not evident for the corn stubble residue. This suggests that type of residue and its orientation within the plough layer can affect residue cover during the year. At Site 2 corn residue cover after spring run-off remained within 1-2 percent of that recorded after ploughing. Over winter forces appear to have had a minimal net effect on cover. At Site 3 residue cover after spring run-off declined on average by 1-3 percent for plots ploughed using the Overum and White ploughs and by approximately 3-8 percent for plots ploughed using the John Deere plough.

See Figures 4-12 for comparisons of residue cover remaining after treatment with the different plough makes and moldboard cuts for all sites.

When after planting soil residue cover was measured, it was found that on Site 1 the third cut on the moldboards for all three plough makes and the second cut on the White plough left significantly more residue cover. The John Deere third cut treatment ranked first with a level of 12 percent followed by the Overum third cut treatment (10%), White third cut treatment (10%) and White second cut treatment (10%). The White first cut treatment left significantly more residue after planting than other treatments on Site 2. On Site 3 the John Deere second cut treatment left significantly more residue (4%) than other treatments.

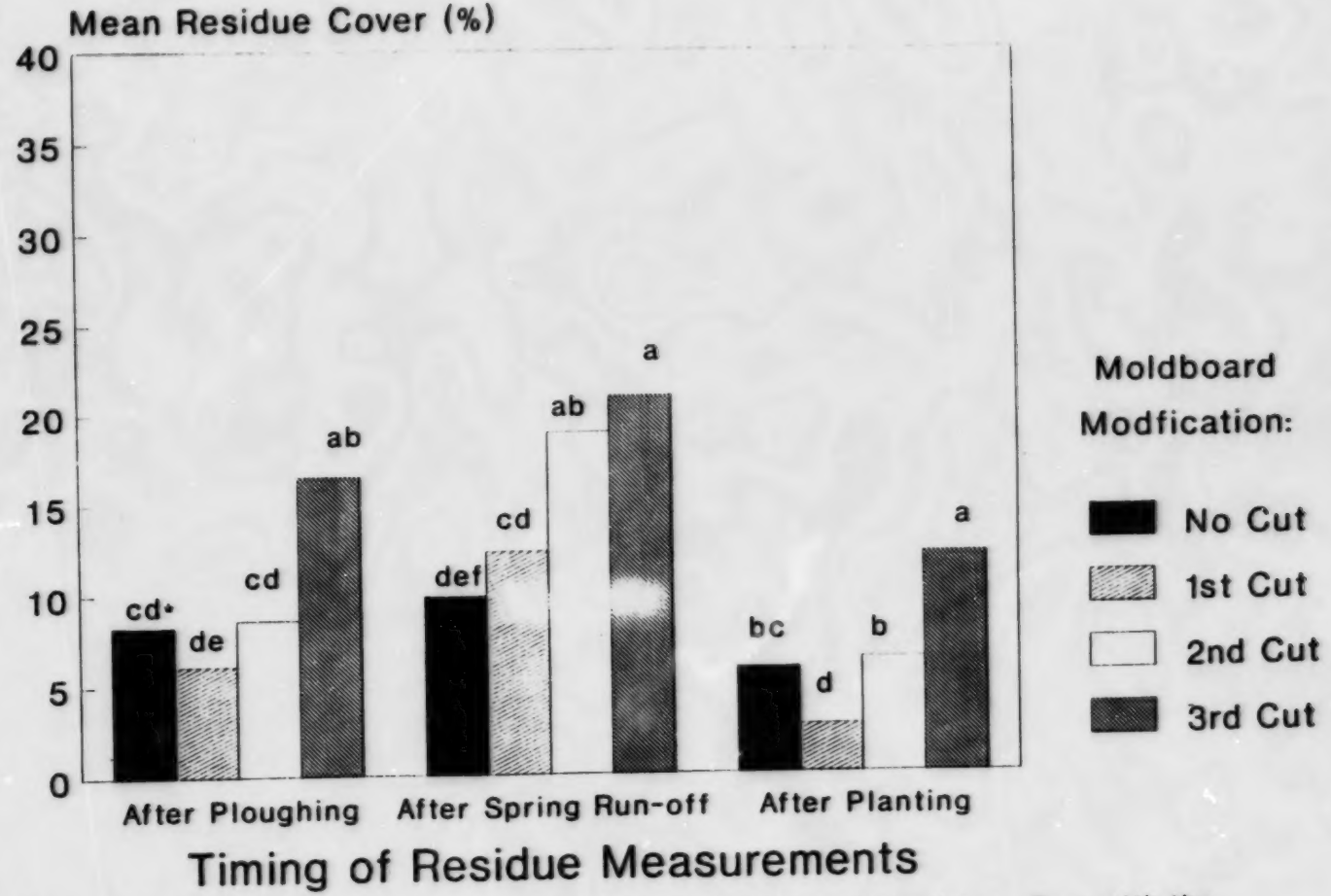
In the spring and early part of summer, 1989 the weather conditions in Essex County were abnormal. Many of the area farmers experienced heavy rains followed by crusting of the soil surface. As a result the seedbed was prepared twice at the grain corn stubble

Figure 4: Cereal stubble soil residue cover using the Overumplough with modified (cut-off) moldboards on clay soil, Comber, Ontario, 1988-89 (Site 1)



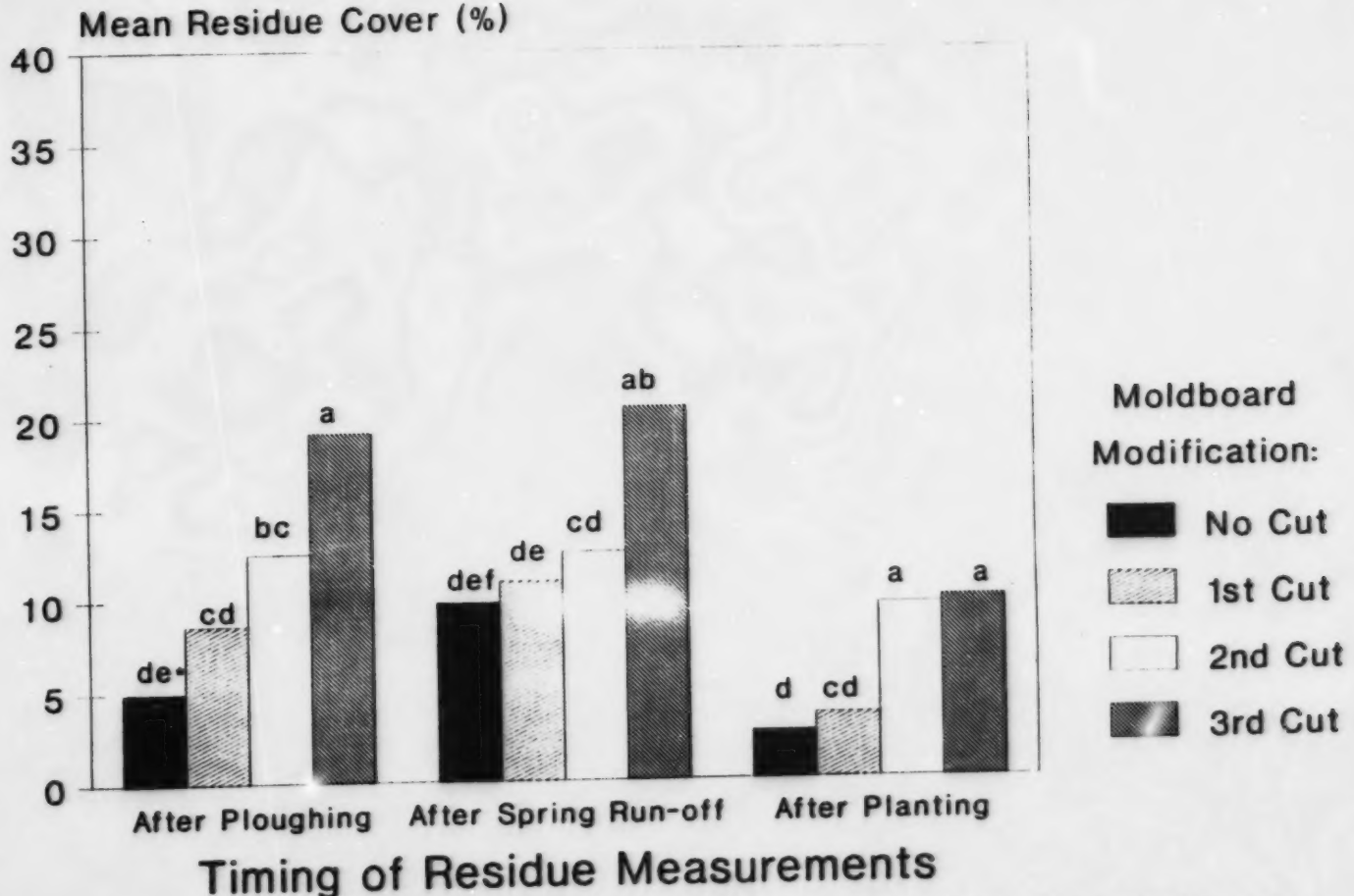
* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 5: Cereal stubble soil residue cover using the John Deere plough with modified (cut-off) moldboards on clay soil, Comber, Ontario, 1988-89 (Site 1)



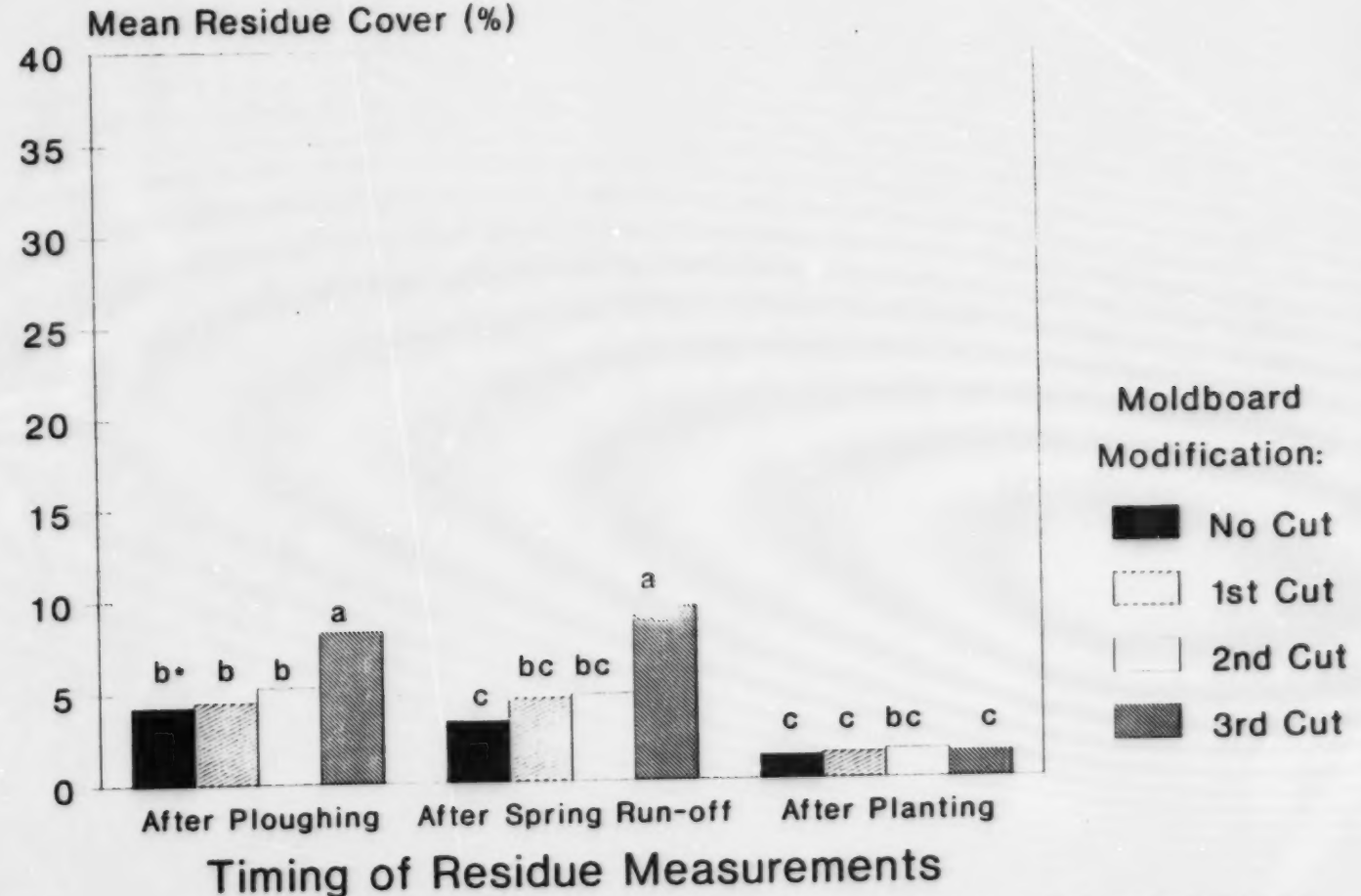
* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5 % level (LSD)

Figure 6: Cereal stubble soil residue cover using the White plough with modified (cut-off) moldboards on clay soil, Comber, Ontario, 1988-89 (Site 1)



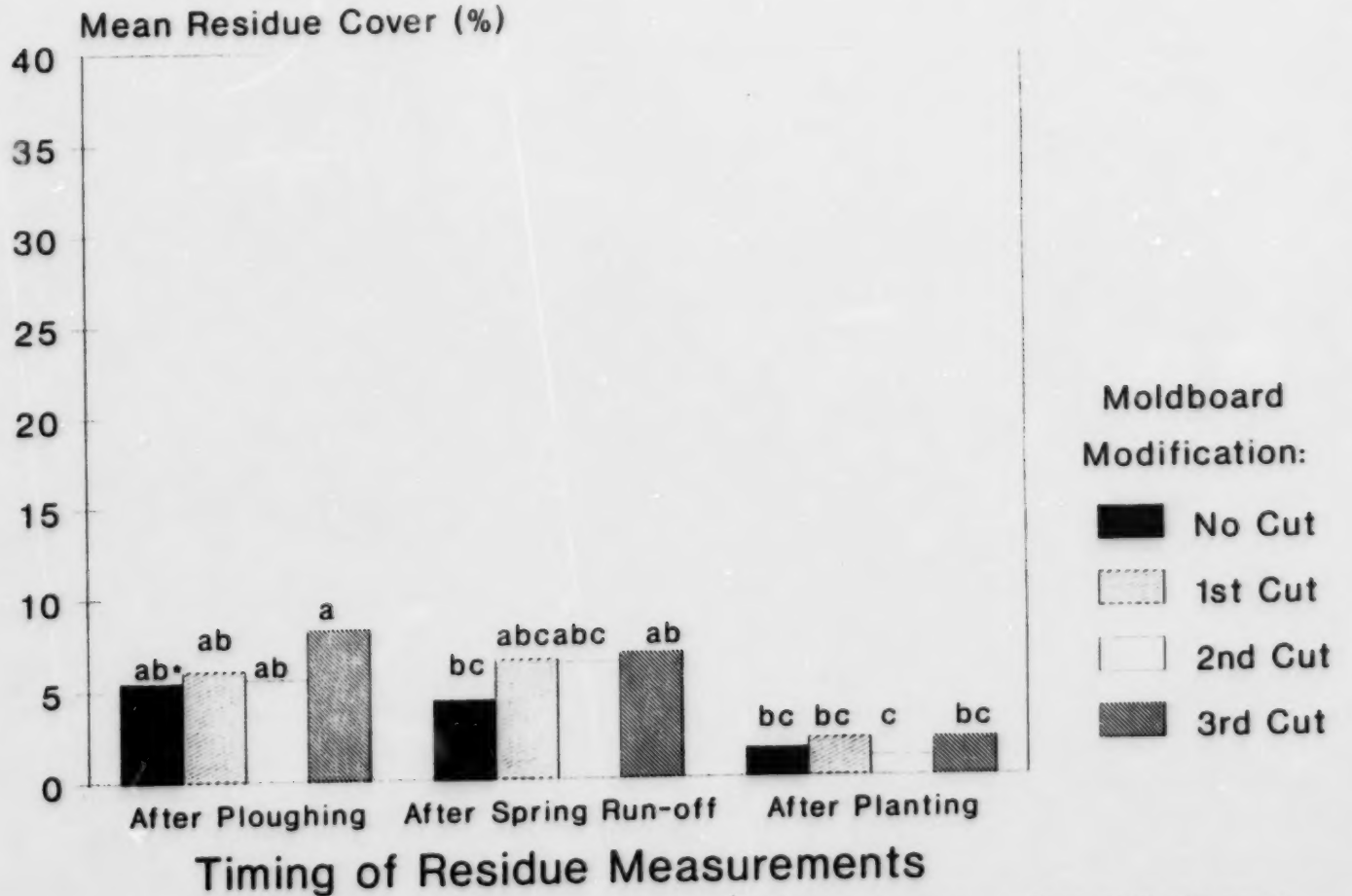
• Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 7: Grain corn stubble soil residue cover using the Overum plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 2)



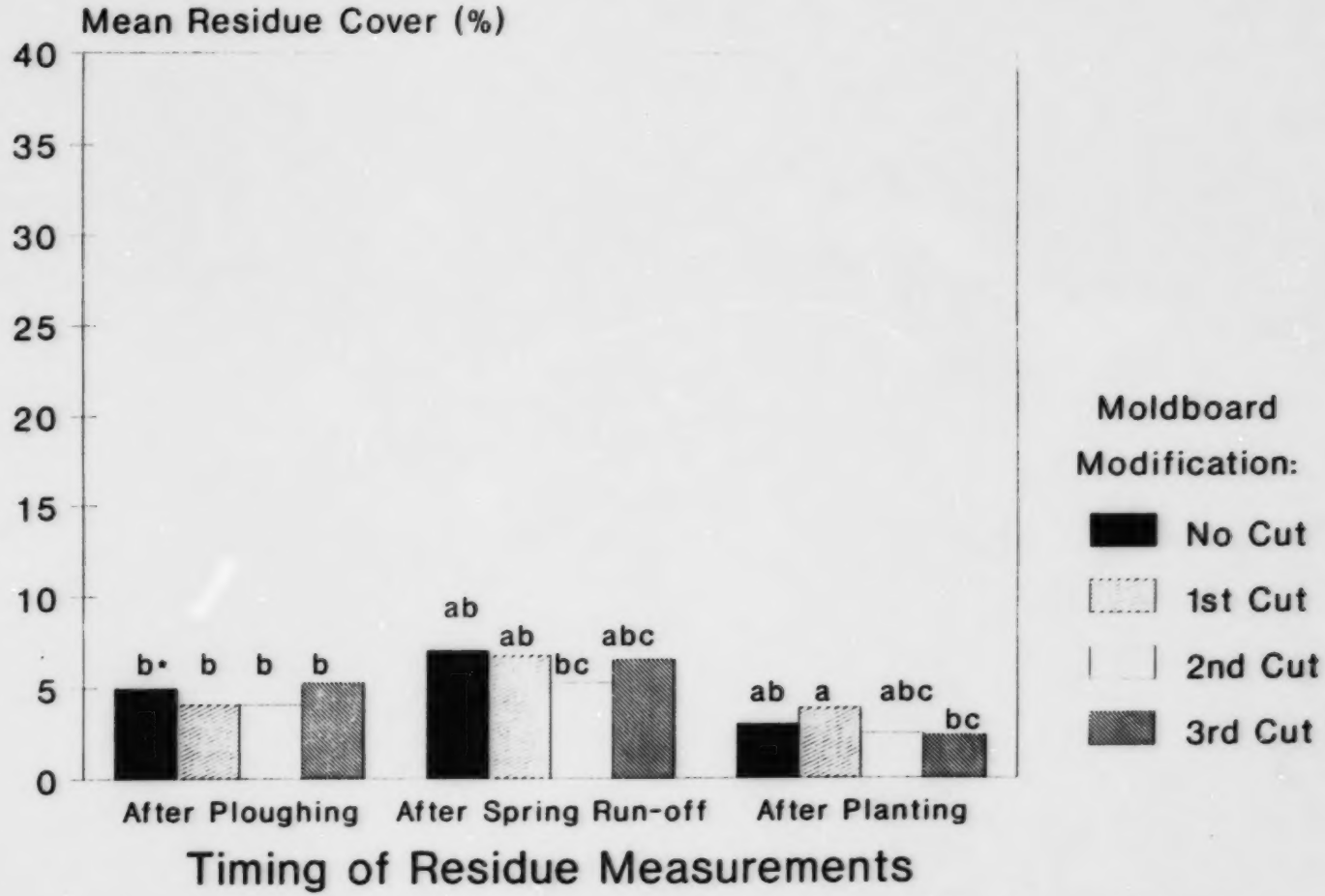
• Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 8: Grain corn stubble soil residue cover using the John Deere plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 2)



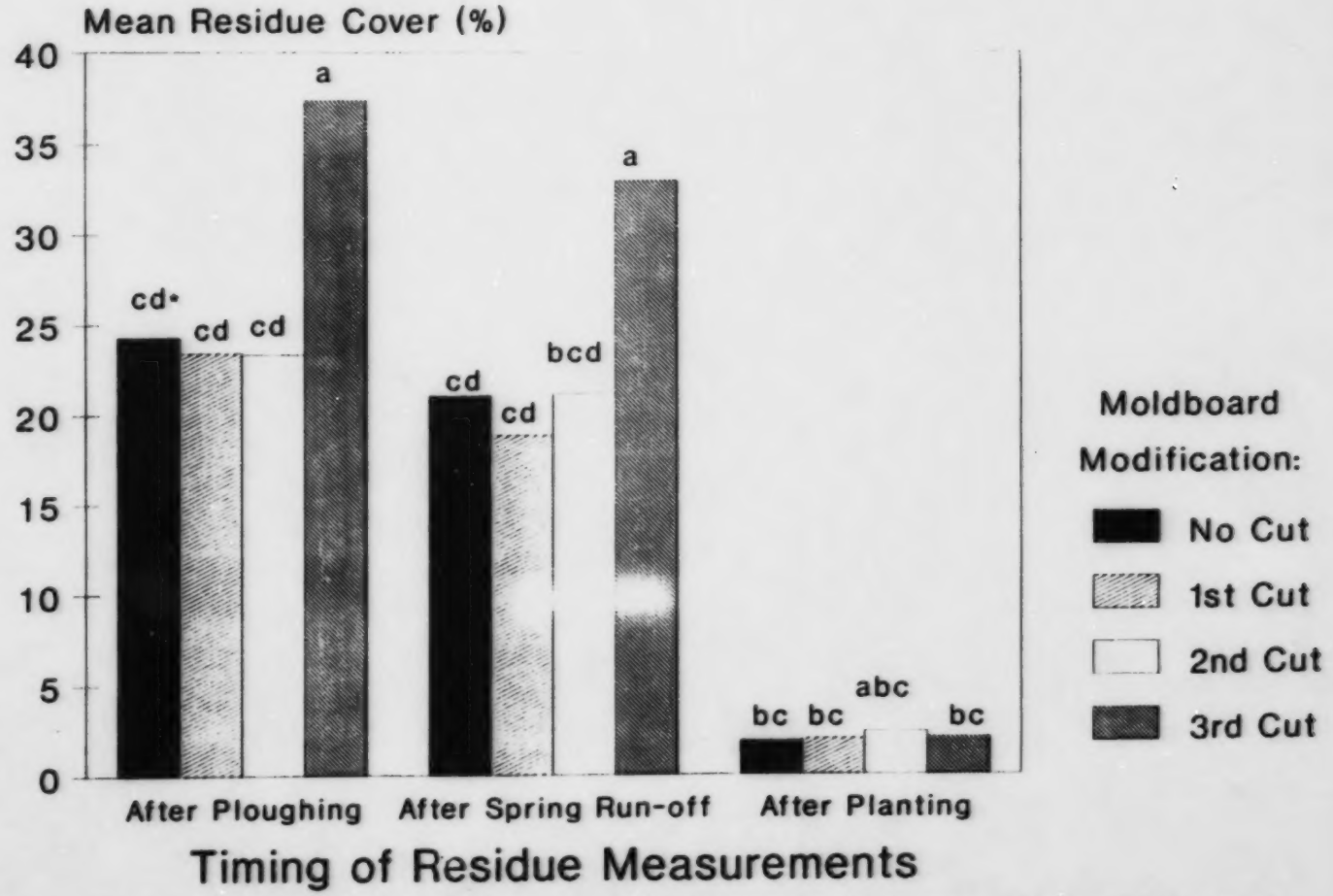
• Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 9: Grain corn stubble soil residue cover using the White plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 2)



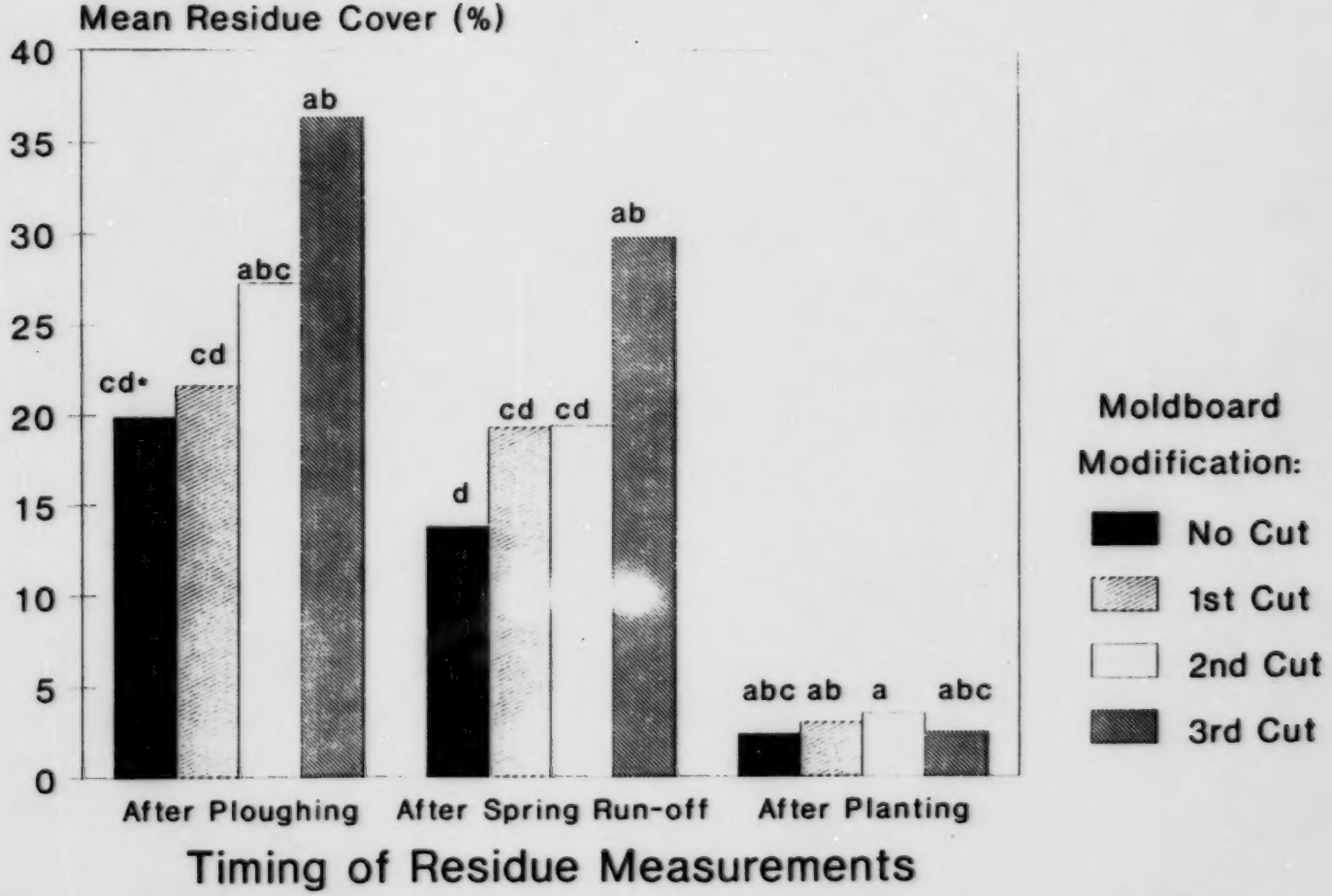
• Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 10: Grain corn stubble soil residue cover using the Overum plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 3)



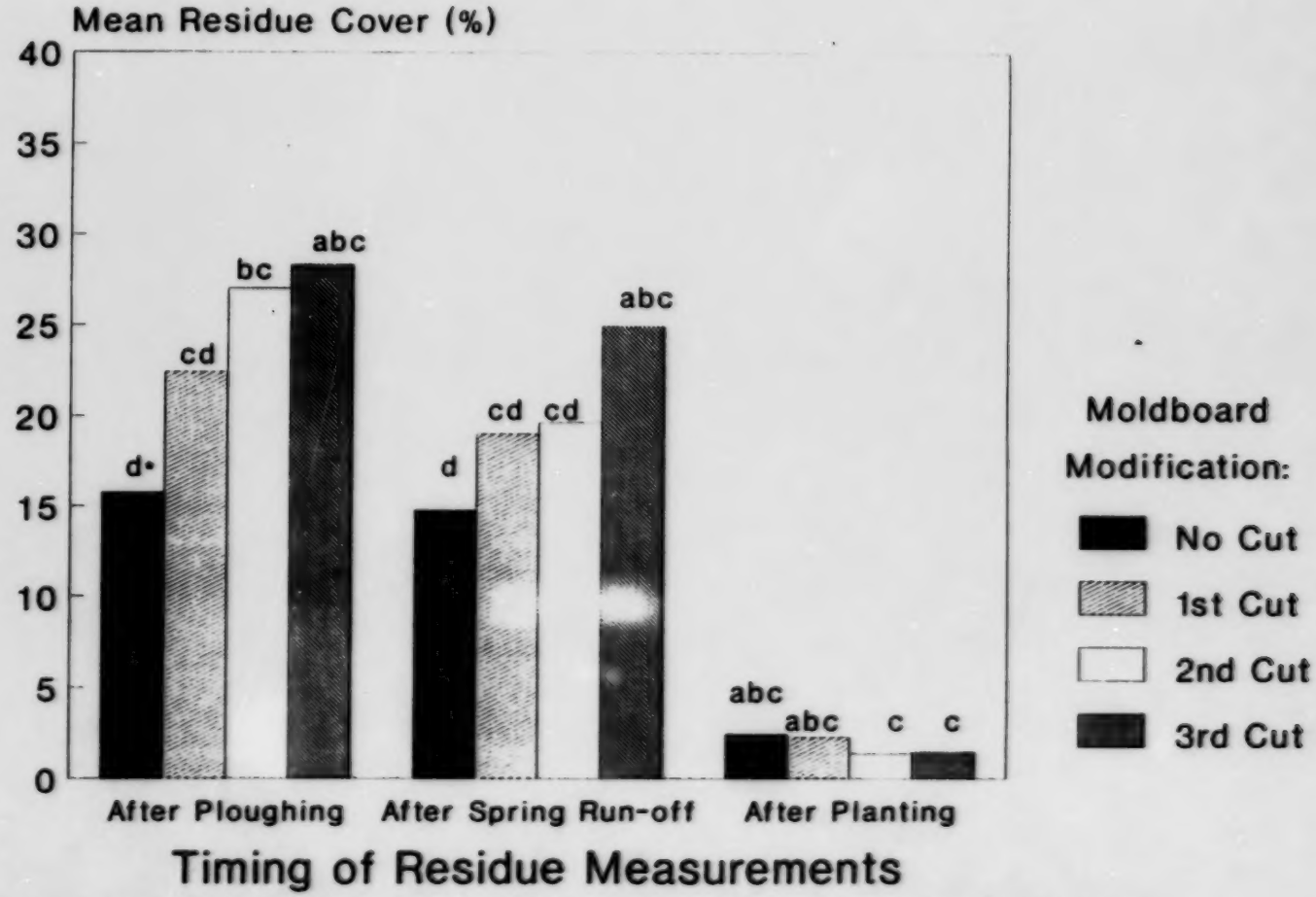
* Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 11: Grain corn stubble soil residue cover using the John Deere plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 3)



• Statistical results shown for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

Figure 12: Grain Corn stubble soil residue cover using the White plough with modified (cut-off) moldboards on clay loam soil, Harrow Ontario, 1988-89 (Site 3)



• Statistical results show for each date are independent from other dates. Bars with the same letter are not significantly different at each date at the 5% level (LSD)

sites. The numerous passes with the equipment may have caused some residue to be destroyed, buried or moved out of the plot area, therefore, having an influence on the amount of residue left after planting.

The amount of soil surface residue left after planting for all treatments at all sites was well below the Ontario benchmark of 20 percent cover needed for soil erosion control. The level of cover at this point in the season was affected not only by the amount of residue left after the primary tillage operation but also by the practices used in the secondary tillage operations. In future, education about residue management and the use of conservation planters may allow producers to minimize the number of passes over the field for seedbed preparation.

4.3 Moldboard Plough Draft

As indicated in the following Figures and Appendix B the specific draft changed with each different plough make and moldboard cut treatment.

At Site 1 the specific draft (Figure 13) declined with each new cut to the moldboards for the Overum plough. The same trend was evident for the John Deere plough except that specific draft rose slightly after the third cut. The draft of the White plough was most affected; increasing sharply on the first cut and then decreasing somewhat and remaining steady for the second and third cuts.

At Site 2 the specific draft (Figure 14) decreased for all ploughs after the first cut, increased after the second and then decreased after the third cut for the Overum and John Deere ploughs after the third cut to the moldboards was made. Specific draft continued to increase for the White plough.

At Site 3 the specific draft (Figure 15) decreased for all ploughs after the first cut. Specific draft increased again for the Overum and White ploughs and decreased for the John Deere plough after the second cut. The third cut treatment caused specific draft to decrease again for the Overum and White ploughs and increase for the John Deere plough. In all cases specific draft was less after the third cut in comparison to no cut.

Figure 13: Site 1,

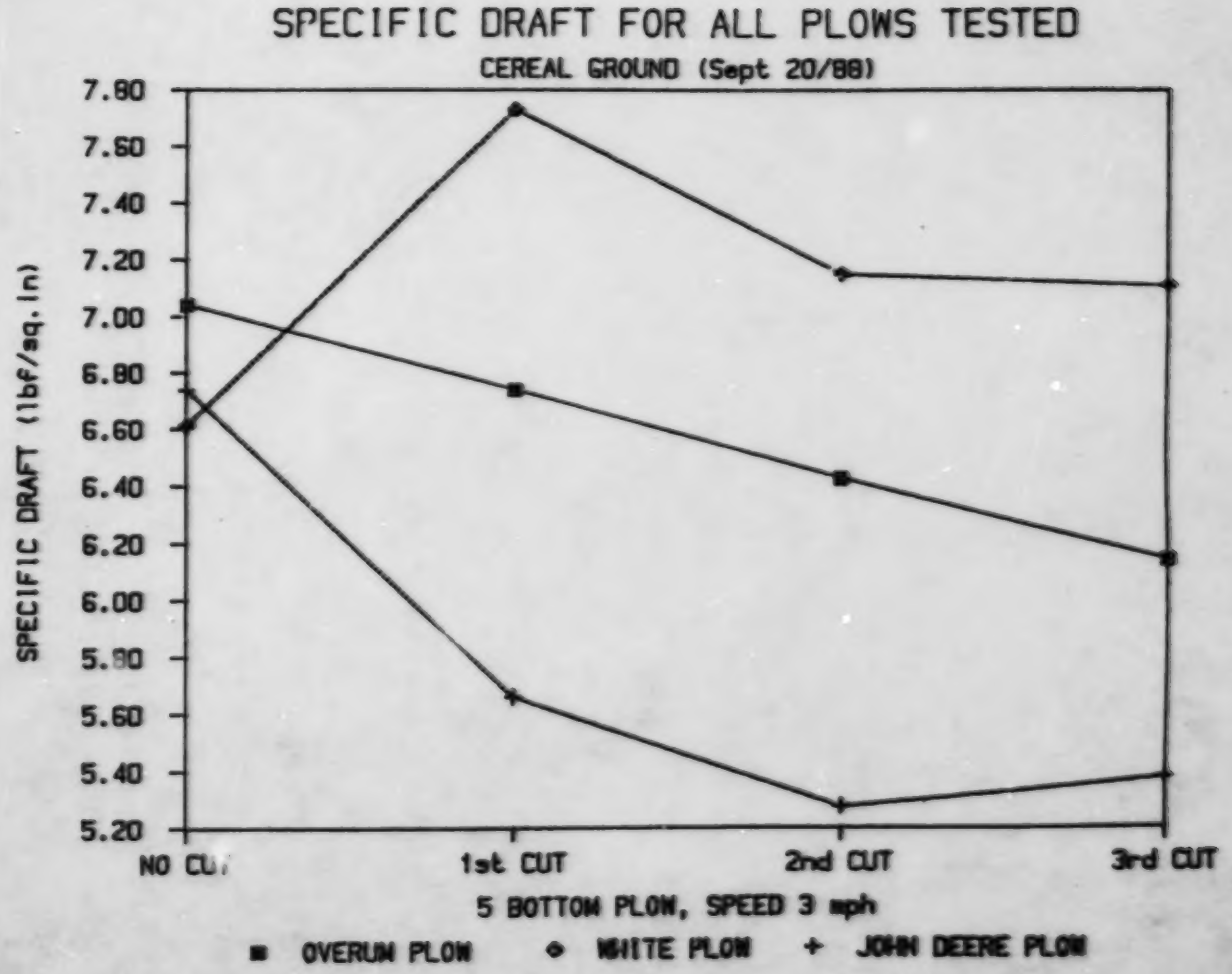


Figure 14: Site 2.

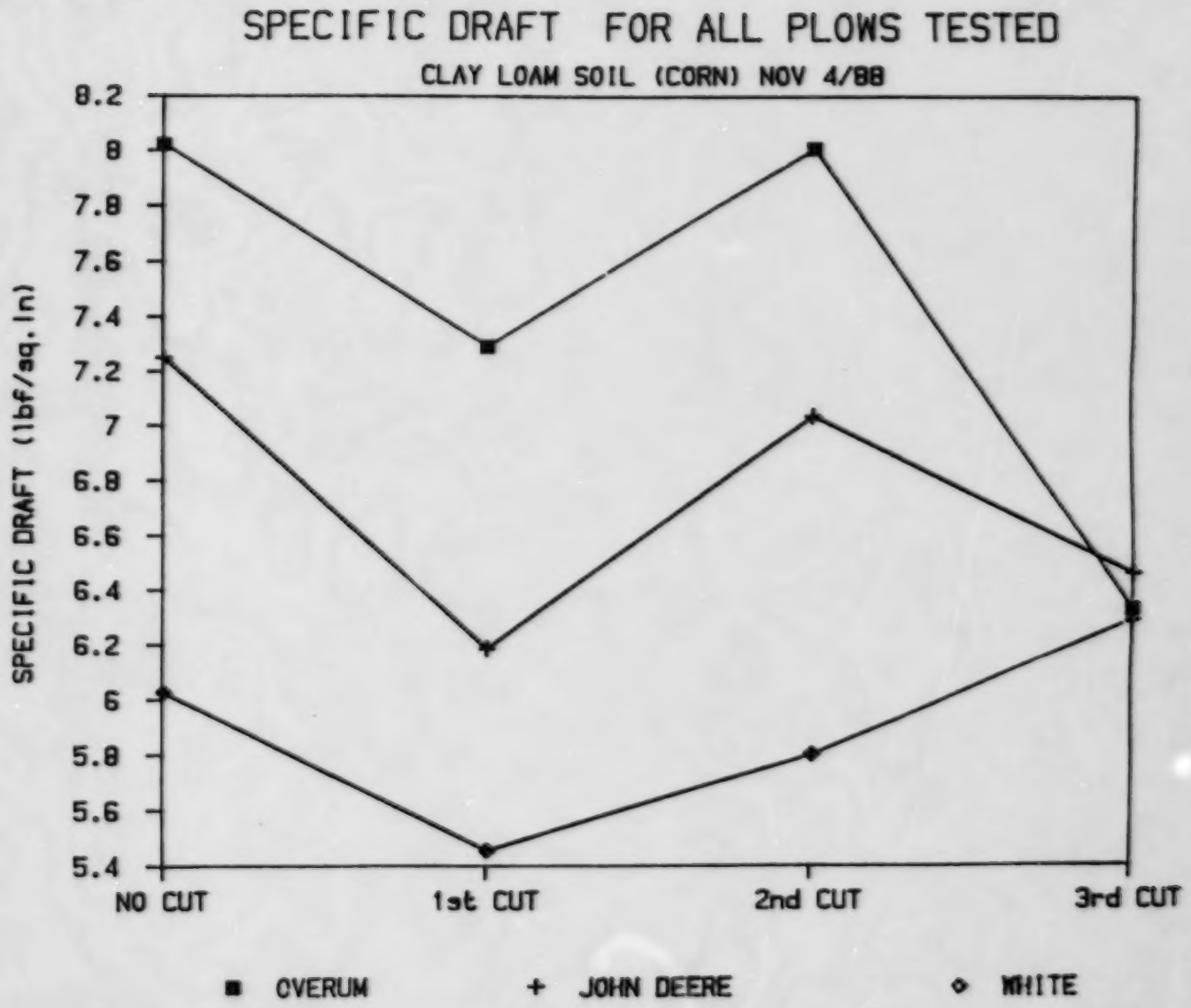
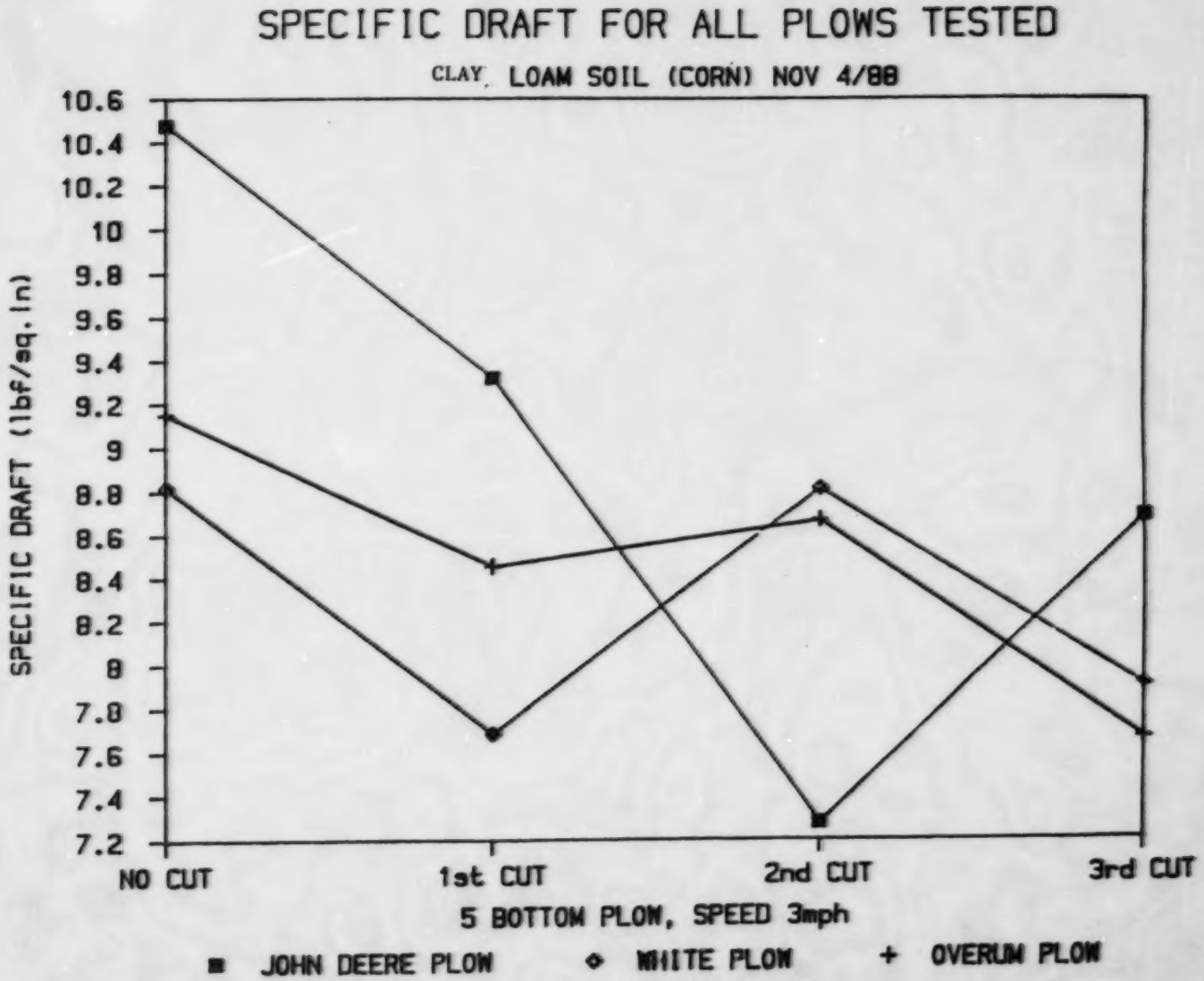


Figure 15: Site 3,



See Figures 17-24 for comparisons of the effect of moldboard cut on individual plough draft at each site. It should be noted that for each plough make one side of the linkage to the tractor (right hand link for the Overum, left hand link for the John Deere and White ploughs) pulled with greater pounds force than the other side of the linkage regardless of moldboard shape. The magnitude of the difference in pull varied somewhat between different moldboard cuts and was not always greater as more cuts were made relative to the pull recorded for full size moldboards.

4.4 Soil Moisture Content

The volumetric soil moisture content prior to treatment implementation was similar across all treatment plots within each site. The highest volumetric moisture content was recorded at Site 3 in early November with values ranging from 35.9 to 40.1 percent. The volumetric moisture content for Site 2 taken at the same time as Site 3, ranged from 32.7 to 36.7 percent. At Site 1 the volumetric moisture content recorded in mid September was considerably lower than at the other sites with values ranging from 20.5 to 24.2 percent (Table 6).

When day of planting volumetric soil moisture content was measured it was found that at Site 2 the values ranged from 19.3 to 21.8 percent and were not significantly different. At Site 3 the volumetric soil moisture content was in general somewhat higher with levels ranging from 21.5 to 30.1 percent.

The volumetric soil moisture content on the day of ploughing and the day of planting were quite similar among treatments plots within each site. As a result the potential effect of soil moisture content on other parameters measured is considered equal across all treatments.

4.5 Soil Surface Smoothness

The soil surface conditions after ploughing tended to be relatively even and smooth for all moldboard treatments except the third cut treatment across all three sites as indicated in Table 7. The roughness of the soil surface after the third cut treatment

Table 6: Volumetric Soil Moisture Content at Ploughing and Planting, Modified Moldboard Study, Essex County, 1988-89

Treatment	Volumetric Soil Moisture Content (%)				
Plough Make/Moldboard Cut	Site 1*	Site 2		Site 3	
	At Ploughing	At Ploughing	At Planting	At Ploughing	At Planting
Overum no cut	21.8	32.7	21.8	40.1	26.0
Overum 1st cut	21.9	33.4	20.5	38.8	22.9
Overum 2nd cut	23.0	35.3	18.6	38.0	22.7
Overum 3rd cut	22.0	33.7	19.0	38.7	24.1
John Deere no cut	24.2	33.9	21.2	38.1	22.4
John Deere 1st cut	21.2	36.7	21.7	36.9	21.5
John Deere 2nd cut	21.3	34.3	21.5	36.6	23.8
John Deere 3rd cut	23.0	35.0	19.8	37.1	22.8
White no cut	21.6	35.3	20.3	39.8	28.1
White 1st cut	20.5	36.7	20.3	35.9	27.4
White 2nd cut	21.0	34.0	19.6	36.9	25.0
White 3rd cut	22.0	36.7	19.3	36.8	30.1
LSD**	2.6	3.6	3.2	4.1	5.6
c.v.	8.2%	7.0%	9.3%	7.5%	15.7%

*Site 1: cereal stubble residue, clay soil, tile drained
Site 2: grain corn stubble residue, clay loam soil, naturally drained
Site 3: grain corn stubble residue, clay loam soil, tile drained

**p=0.05

Table 7: Visual Rating of Soil Surface Smoothness After Ploughing, Modified Moldboard Study, Essex County, 1988-89

Treatment	Soil Surface Rating (0-9=smooth)		
Plough Make/Moldboard Cut	Site 1*	Site 2	Site 3
Overum no cut	6	7	6
Overum 1st cut	7	7	6
Overum 2nd cut	5	6	6
Overum 3rd cut	1	5	4
John Deere no cut	6	7	7
John Deere 1st cut	6	7	6
John Deere 2nd cut	6	7	6
John Deere 3rd cut	0	5	2
White no cut	7	5	7
White 1st cut	7	5	4
White 2nd cut	6	6	7
White 3rd cut	2	6	3

*Site 1: cereal stubble residue, clay soil, tile drained
Site 2: grain corn stubble residue, clay loam soil, naturally drained
Site 3: grain corn stubble residue, clay loam soil, tile drained

Figure 16, Site 1,

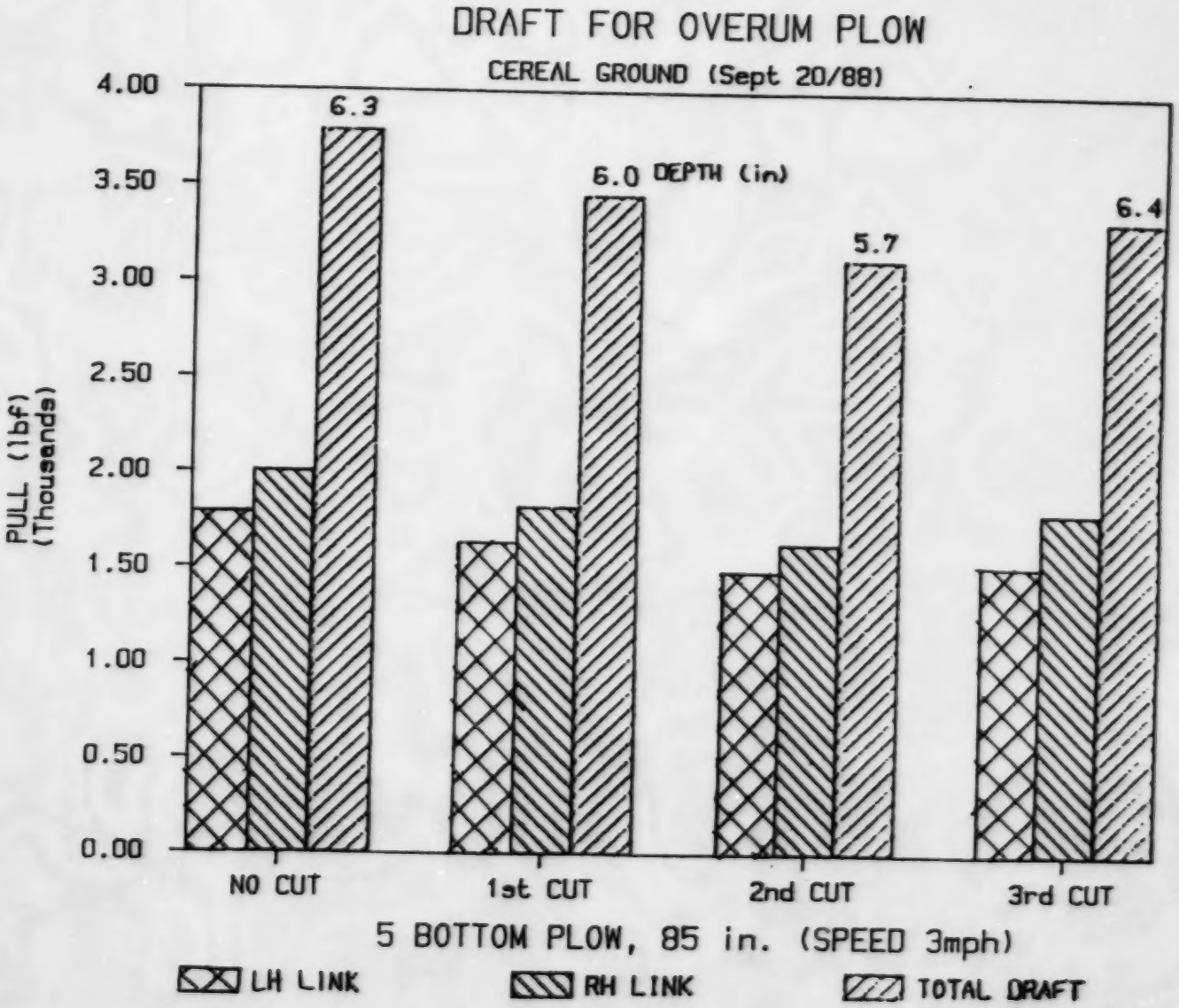


Figure 17: Site 1,

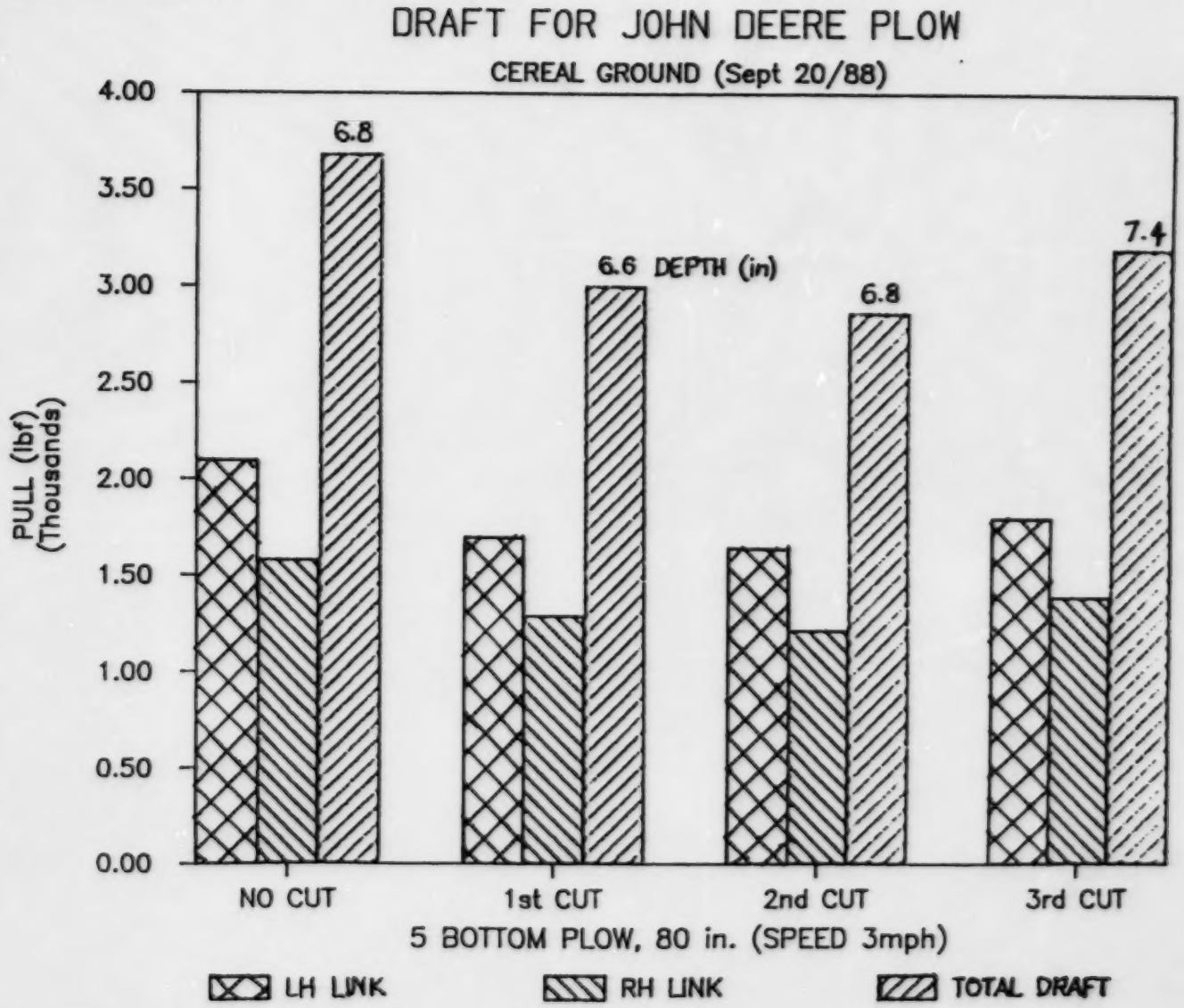


Figure 18: Site 1,

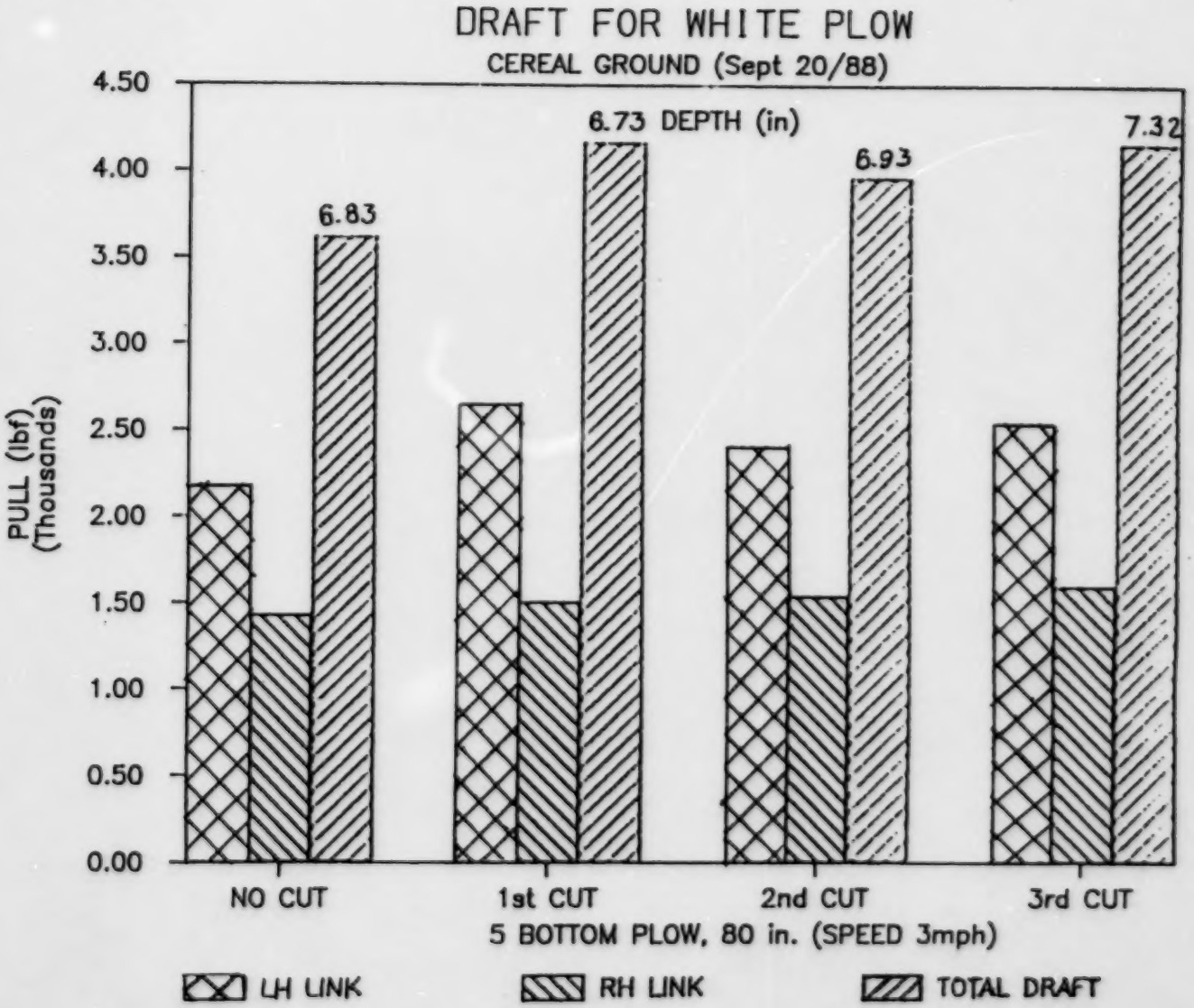


Figure 19:, Site 2,

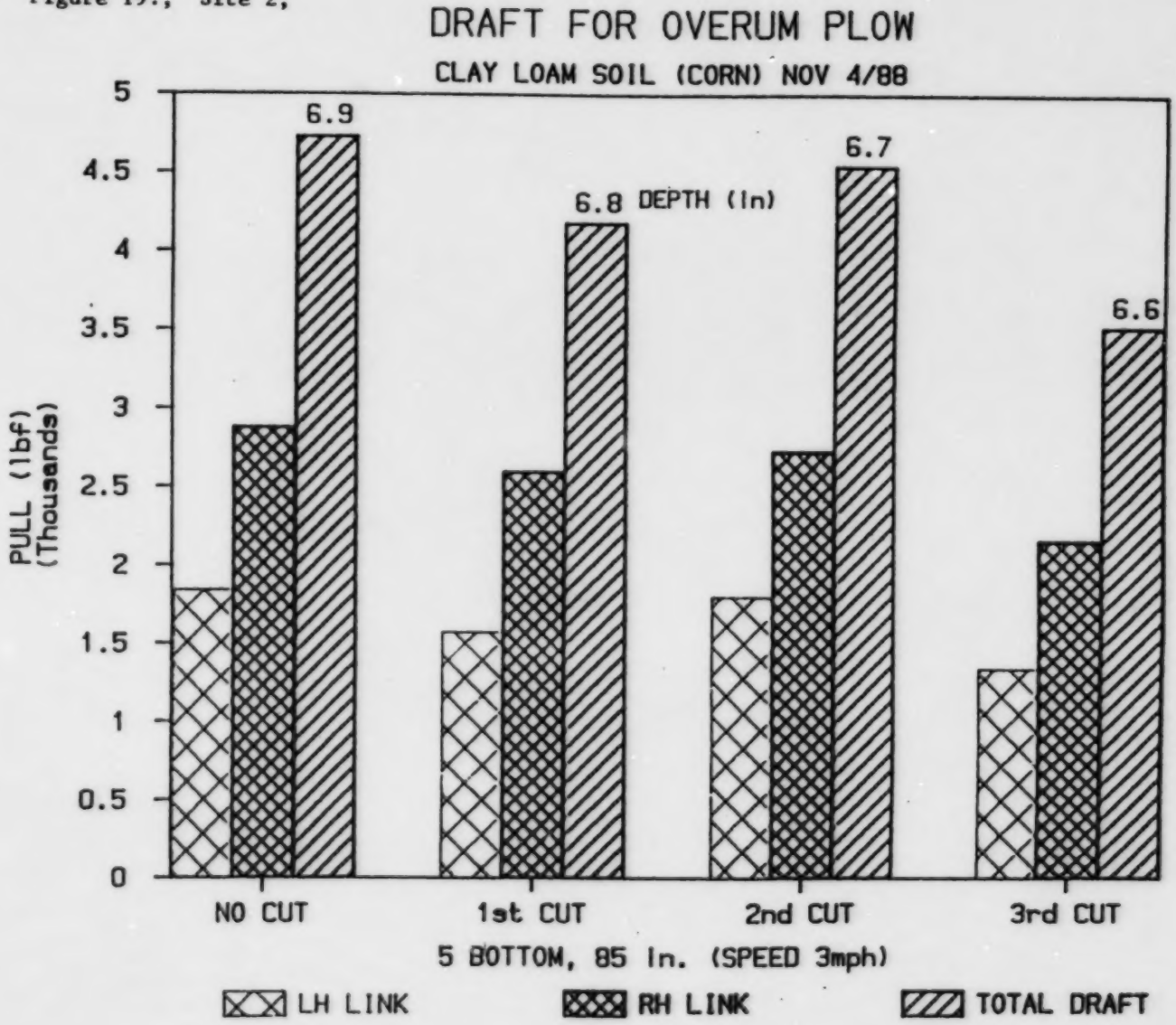


Figure 20: Site 2,

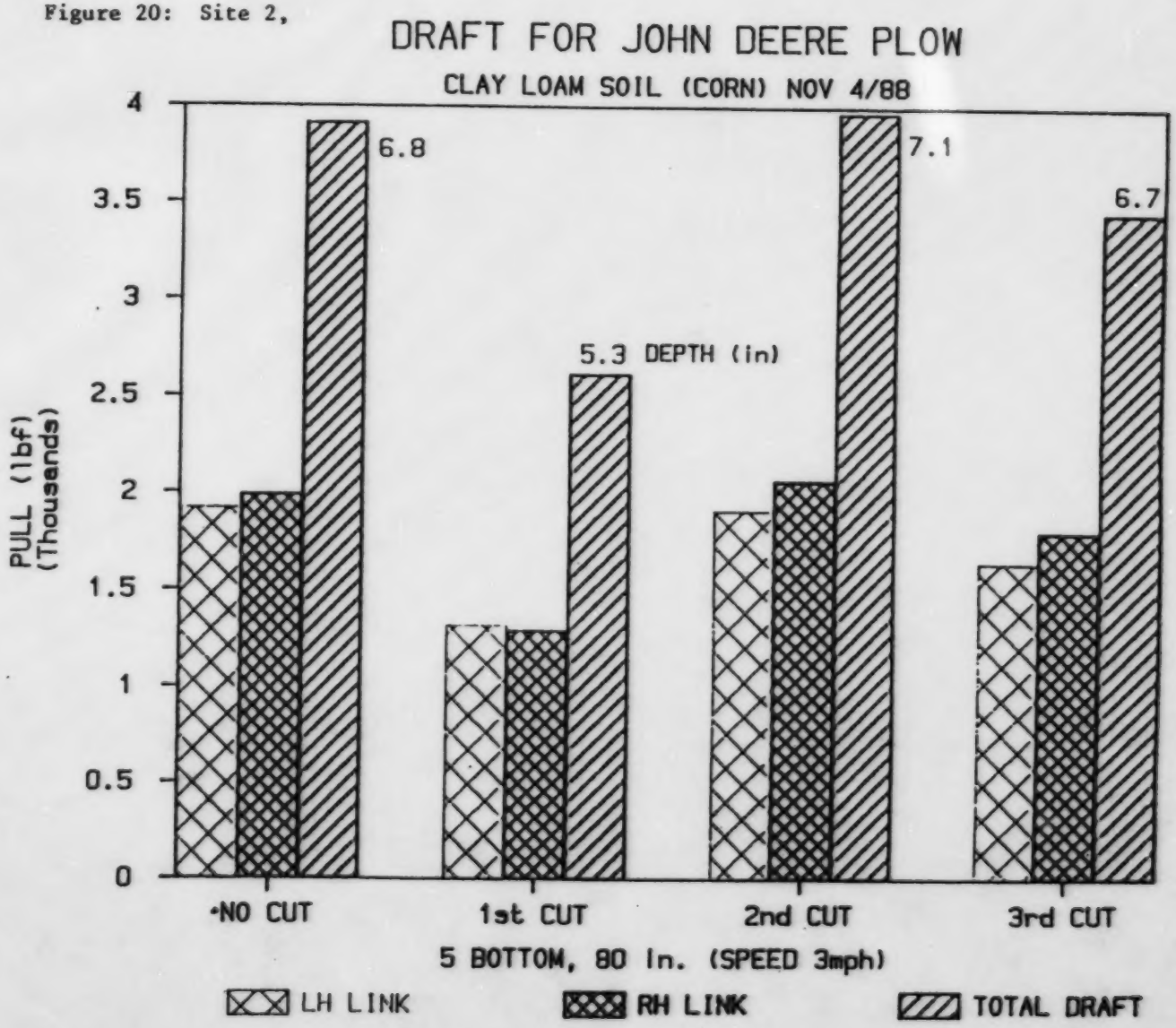


Figure 21: Site 2,

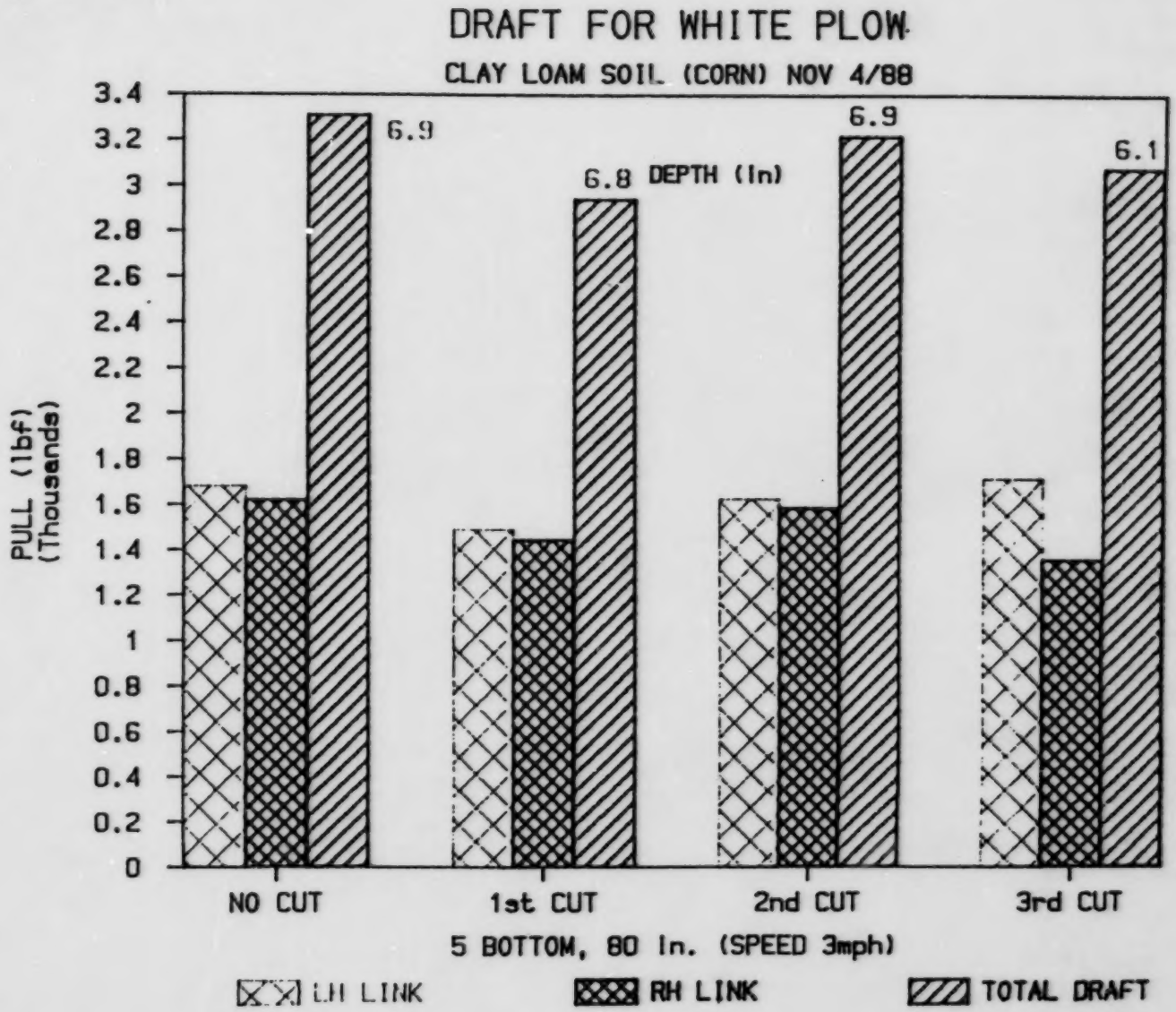


Figure 22: Site 3,

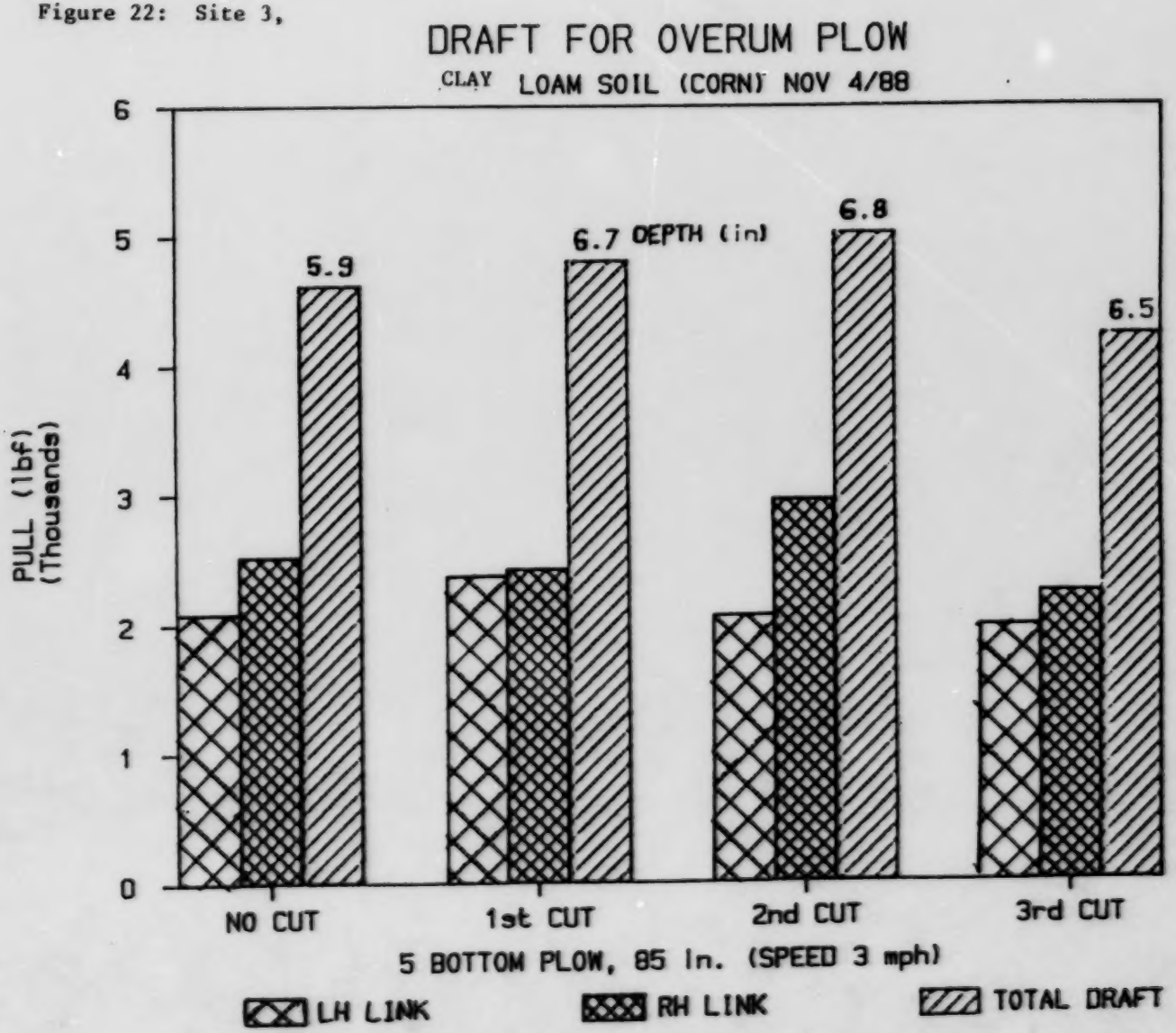


Figure 23: Site 3,

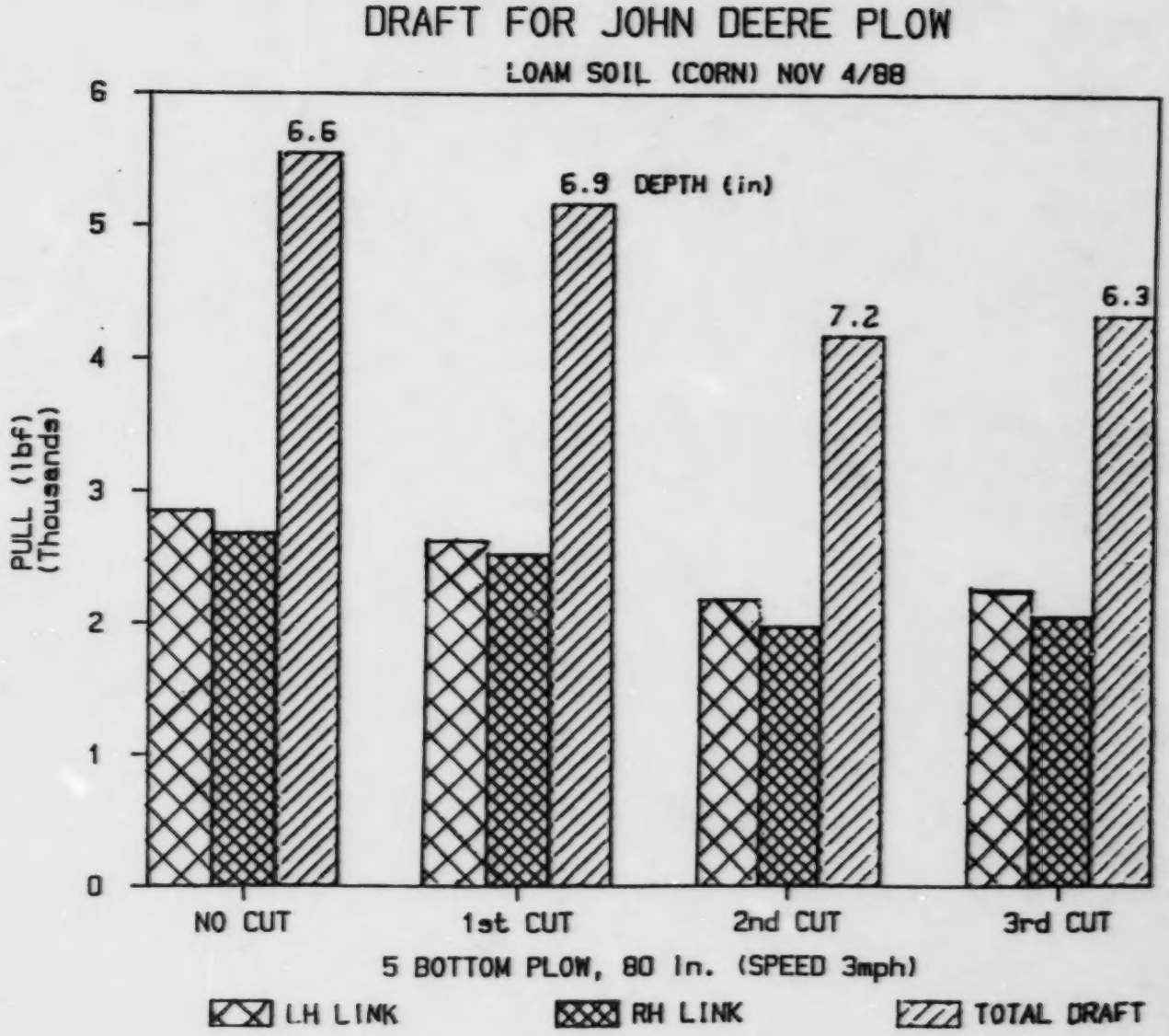
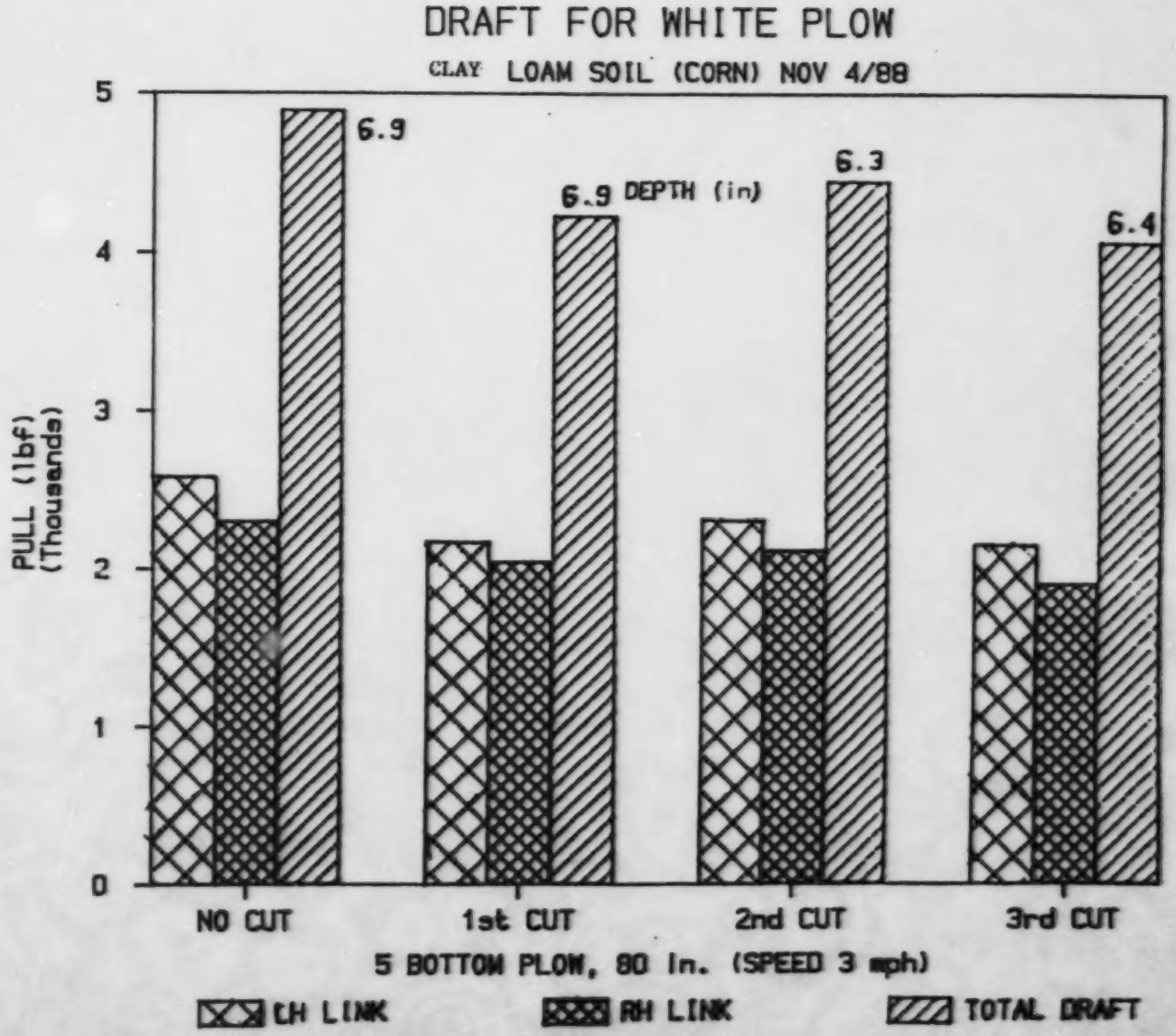


Figure 24: Site 3,



may inhibit adoption of this treatment in the clay plains of Essex. A smooth soil surface is considered essential by producers for proper field drainage and drying in spring. In other counties in Ontario where the slope of the land assists in drainage, roughness of ploughing will not likely inhibit adoption.

4.6 Soybean Plant Emergence

At Site 1 more plants per square meter were measured on the John Deere no cut, White first and third cut, and Overum no and third cut moldboard treatment plots (see Table 8). Significantly fewer soybean plants per square meter were measured on the John Deere first cut treatment plots.

The heavy rains and crusting may have also influenced emergence of the soybean plants. Emergence was uneven throughout each plot and very low where ponding occurred. As a result the cooperator reseeded areas of the field after all data were collected.

4.7 Soybean Plant Vegetative Growth Stage

Table 8 indicates the plant vegetative growth stages recorded at Site 1 (2.95 to 3.2). Plant growth was similar across all treatment considering that heavy rains and soil surface crusting may have affected the rate of vegetative growth at this site.

Table 8: Soybean Plant Emergence and Vegetative Growth Stage on Cereal Stubble Residue on Clay Soil (Site 1), Modified Moldboard Study, Essex County, 1988-89

Treatment Plough Make/Moldboard Cut	Soybean Emergence (plants/m2)	Soybean Vegetative Growth Stage*
Overum no cut	32.2	3.0
Overum 1st cut	23.6	3.1
Overum 2nd cut	27.0	3.0
Overum 3rd cut	34.3	3.2
John Deere no cut	35.5	3.1
John Deere 1st cut	17.9	3.0
John Deere 2nd cut	29.5	3.0
John Deere 3rd cut	29.3	3.0
White no cut	26.3	3.0
White 1st cut	34.3	3.1
White 2nd cut	28.5	3.1
White 3rd cut	35.0	3.0
LSD**	14.0	0.17
c.v.	32.9%	3.9%

* after Fehr, et al.
**p=0.05

5.0 CONCLUSIONS

The following conclusions may be made:

1. Soil residue cover left after ploughing and spring run-off tended to increase as a greater portion of the moldboards was removed.

2. Soil surface smoothness after ploughing tended to decline as a greater portion of the moldboards was removed.

3. At a furrow width of 16 inchs, maintenance of a 6 inch ploughing depth became more difficult as a greater portion of the moldboards was removed.

4. Although the magnitude of the increase in residue cover left on the soil surface after ploughing with modified moldboards was substantial at two of three sites, the actual amount of residue cover remaining after ploughing and spring run-off tended to be slightly less or within 20 to 30 percent.

5. For the Overum and John Deere ploughs, the specific draft tended to decline as a greater portion of the moldboards was removed. Specific draft of the White plough tended to increase at two of three sites.

6.0 RECOMMENDATIONS

In light of the study discussed herein, it is recommended that:

1. Additional studies investigate alternate configurations for cutting the moldboards to provide the most acceptable compromise between amount of moldboard removed, crop residue management potential and soil surface roughness. These studies could be effectively conducted on a large scale field basis by producers in cooperation with SWEEP. This approach would be in keeping with the objectives and plans of TED.

2. Additional studies investigate the effect of furrow width, depth of ploughing and moldboard modification in a variety of soil and crop residue conditions.

3. Additional studies investigate the effect of type and orientation of crop residue on soil surface cover and erosion control potential for Ontario conditions. Interactions between residue type and tillage methods that affect residue orientation, including the moldboard plough, may indicate which combination(s) provide adequate soil erosion control potential.

4. Additional studies investigate the biological, environmental and mechanical influences on crop residue throughout the year for Ontario conditions. If enough residue buried near the soil surface by the moldboard plough is exposed by environmental forces (precipitation) over winter and mechanical forces (secondary tillage) in spring, the moldboard plough may have a role in a systems approach to residue management.

7.0 REFERENCES

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APPENDIX A

Soil Texture Analyses

Soil Texture Analyses

Site	% Sand	% Silt	% Clay
1. Cereal Stubble Clay Loam	20.9	36.1	43.0
2. Grain Corn Stubble Clay Loam	24.6	38.1	37.3
3. Grain Corn Stubble Sandy Loam	27.1	42.8	30.1

APPENDIX B

Moldboard Shape Evaluation Assistance

Report prepared by the Ontario Centre for
Farm Machinery and Food Processing Technology

November 1988

ONTARIO CENTRE FOR
FARM MACHINERY AND
FOOD PROCESSING
TECHNOLOGY

MOLDBOARD SHAPE EVALUATION ASSISTANCE

PROJECT NUMBER 2980

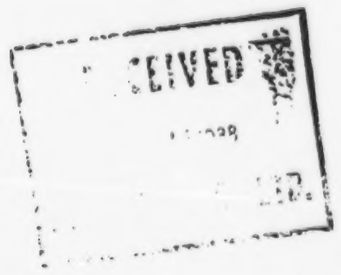
Submitted to:

CMS Research Services
Westmount Place - Suite 225
50 Westmount Road North
Waterloo, Ontario
N2L 2R5

Attention: Ms. Jane Sadler Richards

Submitted by:

Ontario Centre for Farm Machinery
and Food Processing Technology
870 Richmond Street
Chatham, Ontario
N7M 5J5



Attention: Mr. Ashok Newton, P.Eng.
Senior Project Engineer

November, 1988

(Ref-FM130)

TABLE 1 AVERAGE OF FOUR REPLICATIONS IN CEREAL GROUND (Sept 20, 1988)

LH PULL (lb)	RH PULL (lb)	TOTAL DRAFT(lbf)	SPECIFIC DRAFT (lbf/sq.in)	DEPTH (in)	MOLDBOARD AREA (sq in)	% AREA OF MOLDBOARD	
1781	2006	3788	7.0	6.3	426	100	OVERUM NO CUT
1629	1824	3454	6.7	6.0	343	81	OVERUM 1st CUT
1489	1639	3128	6.4	5.7	269	63	OVERUM 2nd CUT
1531	1811	3342	6.1	6.4	147	35	OVERUM 3rd CUT
2098	1584	3682	6.7	6.8	355	100	JOHN DEERE PLOW NO CUT
1708	1293	3000	5.7	6.6	274	77	JOHN DEERE 1st CUT
1645	1220	2865	5.3	6.8	236	66	JOHN DEERE 2nd CUT
1801	1399	3200	5.4	7.4	147	41	JOHN DEERE 3rd CUT
2181	1432	3613	6.6	6.8	319	100	WHITE PLOW NO CUT
2651	1511	4162	7.7	6.7	240	75	WHITE PLOW 1st CUT
2413	1549	3962	7.1	6.9	197	62	WHITE PLOW 2nd CUT
2551	1611	4161	7.1	7.3	104	33	WHITE PLOW 3rd CUT

TABLE 2 AVERAGE PULL IN CLAY LOAM SOIL
NOV 4/88

ACTUAL PULL LH LINK (lbf)	ACTUAL PULL RH LINK (lbf)	SPECIFIC DRAFT (lbf/sq.in)	TOTAL PULL (lbf)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
						OVERUM
1852	2880	8.0	4732	6.9	CL	NO CUT
1586	2598	7.3	4184	6.8	CL	1st CUT
1816	2736	8.0	4552	6.7	CL	2nd CUT
1358	2173	6.3	3531	6.6	CL	3rd CUT
1926	1990	7.3	3916	6.8	CL	NO CUT JOHN DEERE
1322	1292	6.2	2614	5.3	CL	1st CUT JOHN DEERE
1913	2062	7.0	3974	7.1	CL	2nd CUT JOHN DEERE
1651	1804	6.5	3456	6.7	CL	3rd CUT JOHN DEERE
1689	1625	6.0	3314	6.9	CL	NO CUT WHITE
1498	1447	5.5	2945	6.8	CL	1st CUT WHITE
1632	1590	5.8	3221	6.9	CL	2nd CUT WHITE
1722	1359	6.3	3081	6.1	CL	3rd CUT WHITE

FOOD PROCESSING
TECHNOLOGY

December 12, 1988

Ms. Jane Sadler Richards
CMS Research Services
Westmount Place
50 Westmount Road North
Suite 225
Waterloo, Ontario

Dear Jane:

Enclosed are two copies of the report entitled "Moldboard Shape Evaluation Assistance", Project 2980. I have also enclosed the video tape and all the pictures that were taken in the field.

There are three graphs in the report that show the specific draft of all the plow bottoms that were tested in the field. To clarify what specific draft is, I have enclosed photocopies of some pages from the book, "Principles of Farm Machinery", for your reference.

It was a pleasure working with you and your staff. If you have any questions, please call me.

Yours truly,

Ashok Newton, P.Eng.
Senior Project Engineer

AN:clc
Enclosures

RECEIVED
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INTRODUCTION

CMS Research Services undertook a soil tillage research project under the federal government's Soil and Water Environment Enhancement Program (SWEEP). One objective was to study the effect of modified moldboard shapes on surface residue cover.

CMS Research Services, a research and development company, does not have in-house mechanical engineering capabilities and, therefore, approached the Ontario Centre for Farm Machinery and Food Processing Technology for assistance.

The Centre's primary contributions were in the areas of moldboard plow identifications, selection, draft measurement, moldboard modifications, and plow-hitch modifications.

A number of plow makes were identified and, in consultation with Jane Sadler Richards, three plows (Overum, White and John Deere) were selected and tested in the field. Preliminary tests were carried out in cereal ground to determine the most suitable cuts to be made on the moldboard. The three plows were tested in clay loam and sandy loam soils that had surface corn residue.

For <u>each</u> plow, draft measurements were recorded:

(i) using the unaltered shape; and
(ii) using three progressively altered shapes.

WORK DONE

PLOW SELECTION

The three plows selected for the trials were Overum, White and John Deere.

ITEM	OVERUM	WHITE	JOHN DEERE
Number of bottoms	5	5	5
Moldboard part #	6-6158060490	10-UL-619-16	10-NU 1036
Moldboard type	V-body, European	general purpose	high speed
Stone release	hydraulic	manual reset	manual reset

PLOW ADJUSTMENT AND SET-UP

The plows were adjusted and set, both vertically and laterally, to operate at a sixteen-inch width per bottom and a depth of about six inches.

DRAFT MEASUREMENT

A draft measuring unit (Figure 1), designed and built at the Centre, was mounted between the tractor hitch and the plow. Two load cells measured the pull in the left and right lower links of the tractor's 3-point hitch. The load cell output was displayed on two digital display units and the readings were recorded for each pass.

MOLDBOARD SHAPE MODIFICATIONS

Four shapes were selected for each moldboard. The cut locations on the moldboard were made such that they could be easily communicated to the end user.

Figures 2 to 8 show the location of the cuts on the three moldboards. The first cut was made 1.5 inches behind the bolt hole for the brace. The second cut was across the top, starting 3.0 inches away from the top of the shin, and kept 1.5 inches above the brace bolt hole. The third cut was parallel to the shin, starting from the trailing edge of the share.

The Overum plow required a new bracket to hold the reversible plow point because the existing bracket was removed with the third cut (Figure 8).

After the first, second and third cuts, the effective moldboard area left was about 77%, 62%, and 35% respectively (Figure 9 to 11).

DRAFT OBSERVATIONS

Tables 1 to 3 show the average of the observations taken in the field for the three plows tested with the various cuts. Figures 12 to 14 show the specific draft for each treatment. (Reference: "Principles of Farm Machinery", Kepner, Bainer & Bauger, AVI, page 151-155.)

$$\text{Specific Draft of Plow } (\text{lbf/in}^2) = \frac{\text{Total Draft (lbf)}}{\text{Depth of Cut (in.)} \times \text{Total Plow Width (in.)}}$$

Figures 15 to 17 show the draft observed in clay loam soil (cereal).

Figures 18 to 20 show the draft observed in clay loam soil (corn).

Figures 21 to 23 show the draft observed in sandy loam soil (corn).

The actual observations taken in the field are shown in Appendix A.

All work requested in the contract has been completed. No conclusions or recommendations are being made in this report, as CMS Research will be using this report as background information for its broader-based project.

Figure 1: Draft Measuring Unit mounted between the tractor and plow.

Figure 2: Full Moldboard on John Deere plow.

Figure 3: First cut on John Deere plow.

Figure 4: Second cut on John Deere plow.

Figure 5: Third cut on John Deere plow.

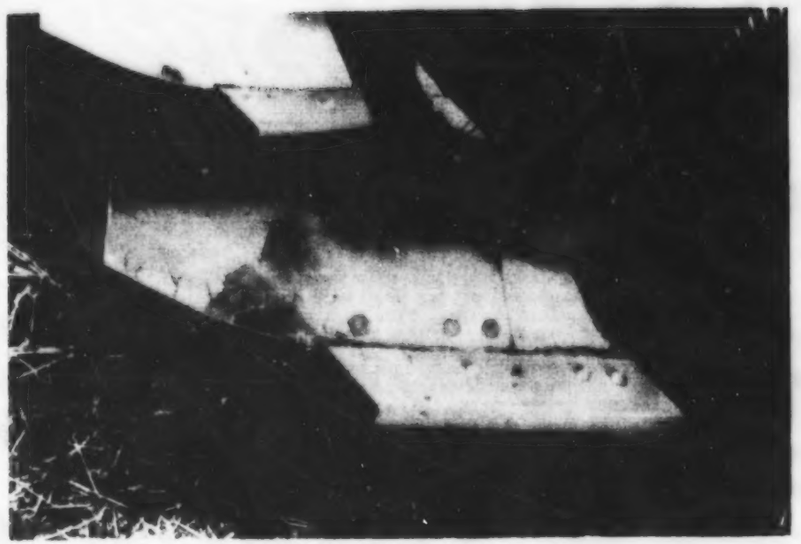
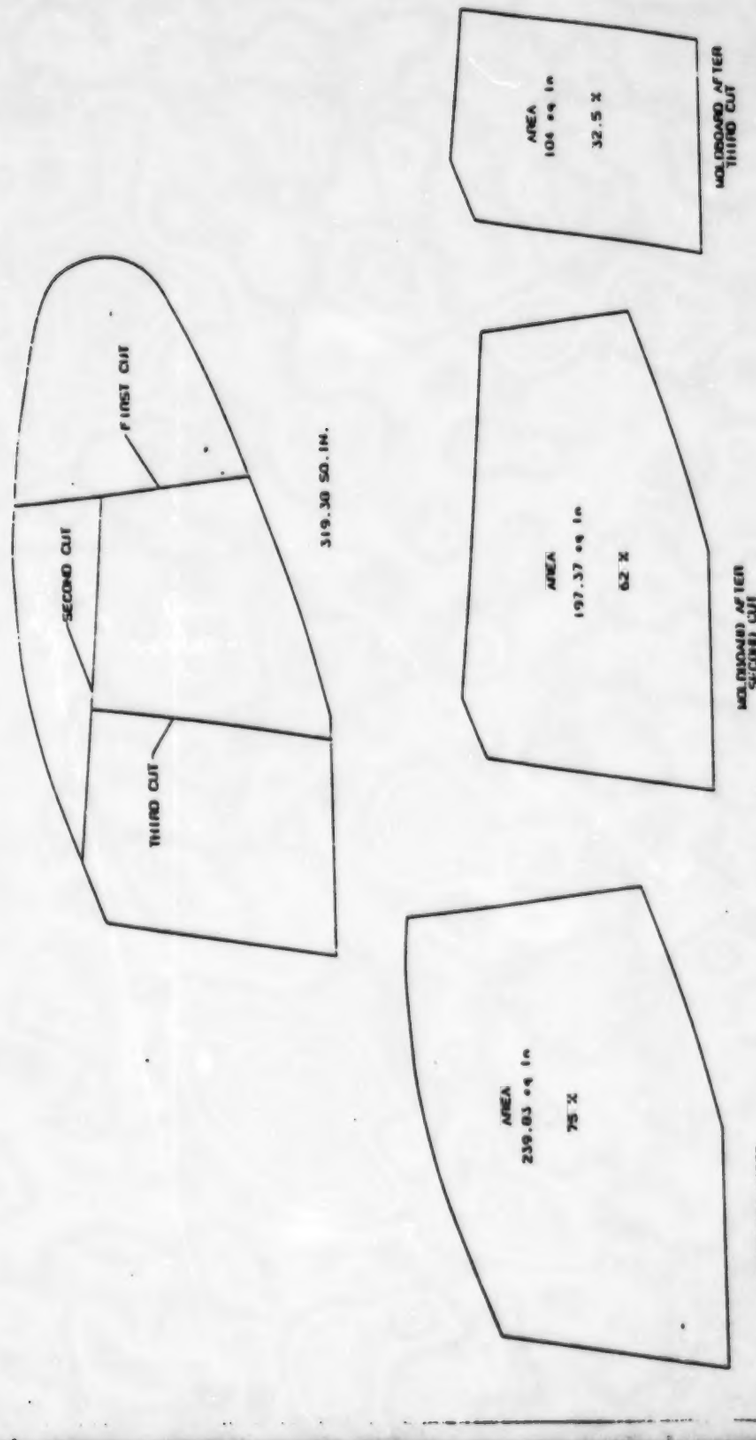


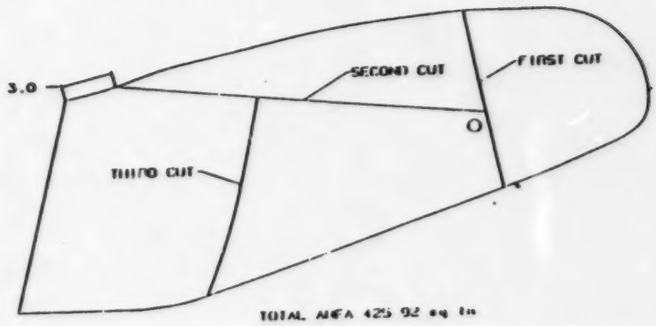
Figure 6: Second cut on White Plow. (also shown is the mark for the third cut).

Figure 7: Second cut of the Overum plow.

Figure 8: Third cut on the Overum plow.

Figure 9





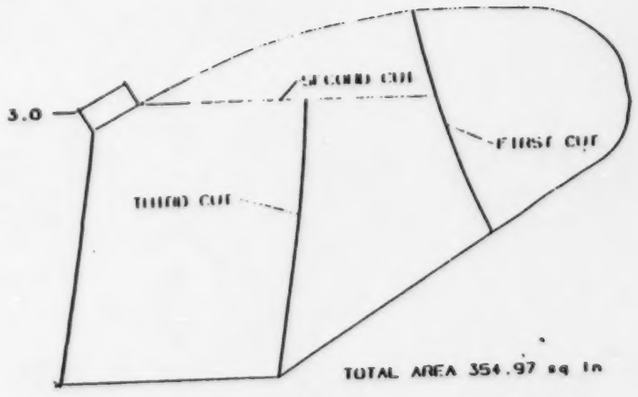
MOLDBOARD AFTER FIRST CUT

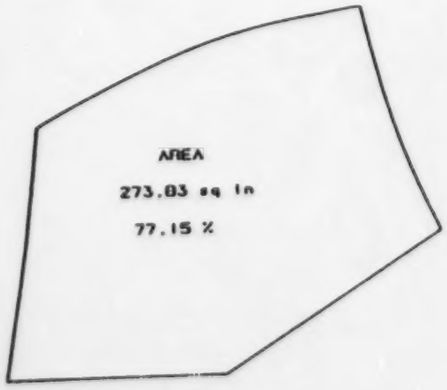
MOLDBOARD AFTER SECOND CUT

MOLDBOARD AFTER THIRD CUT

OVERUM PLOW MOLDBOARD (GENERAL PURPOSE)

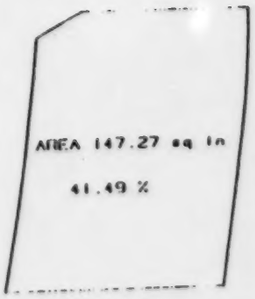
Figure 10





MOLDBOARD AFTER FIRST CUT

MOLDBOARD AFTER SECOND CUT



MOLDBOARD AFTER THIRD CUT

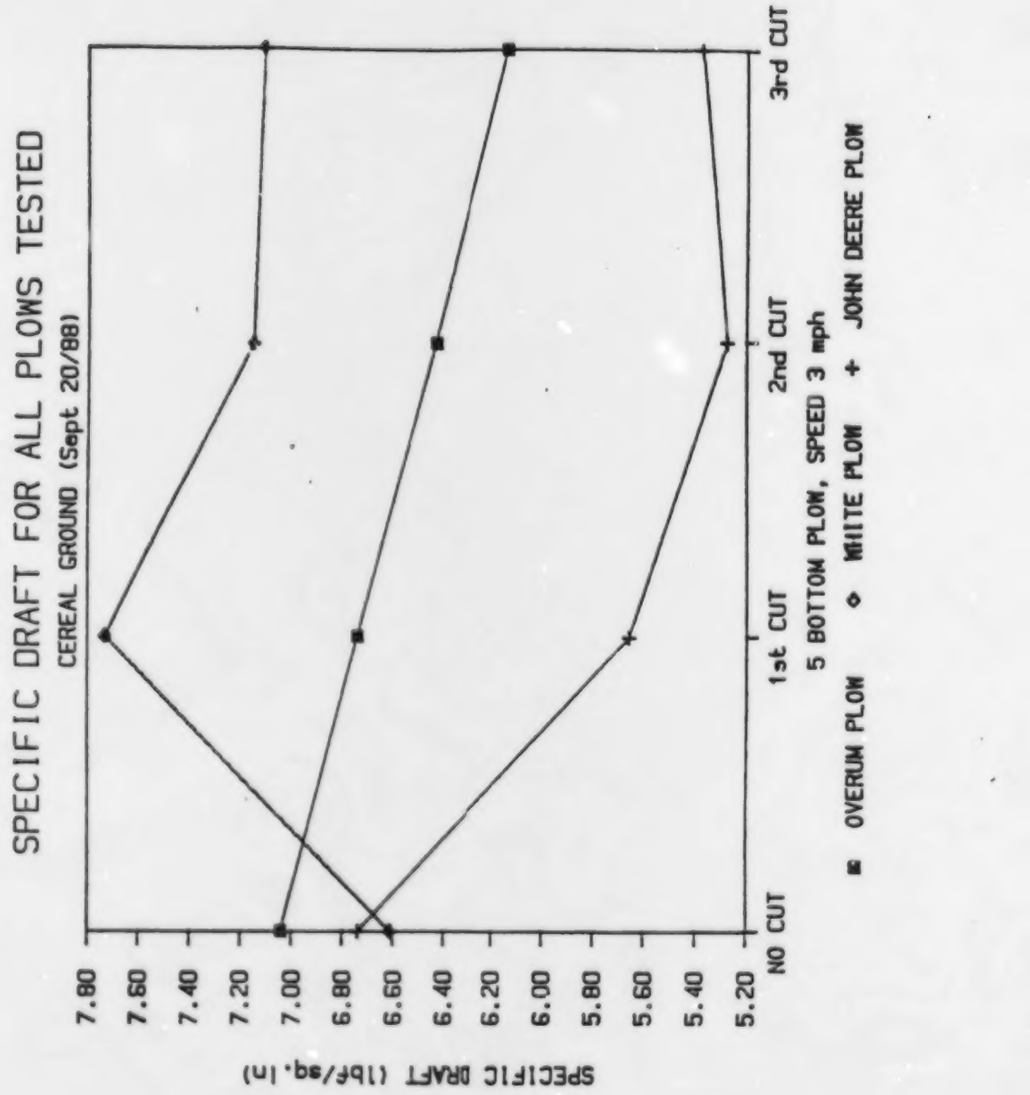
JOHN DEERE PLOW MOLDBOARD (HIGH SPEED)

Figure 11

TABLE 3 AVERAGE OF FOUR REPLICATIONS IN SANDY LOAM SOIL (SL)

ACTUAL PULL LH LINK (lbf)	ACTUAL PULL RH LINK (lbf)	SPECIFIC DRAFT (lbf/sq.in)	TOTAL DRAFT (lbf)	DEPTH (in)	SOIL TYPE	PLOW CUT/TYPE
						OVERUM
2093	2526	9.2	4619	5.9	SL	NO CUT
2379	2429	8.5	4807	6.7	SL	1st CUT
2066	2955	8.7	5021	6.8	SL	2nd CUT
1988	2245	7.7	4234	6.5	SL	3rd CUT
2863	2689	10.5	5553	6.6	SL	NO CUT JOHN DEERE
2641	2531	9.3	5173	6.9	SL	1st CUT JOHN DEERE
2199	1987	7.3	4186	7.2	SL	2nd CUT JOHN DEERE
2276	2069	8.7	4345	6.3	SL	3rd CUT JOHN DEERE
2587	2306	8.8	4893	6.9	SL	NO CUT WHITE
2178	2049	7.7	4227	6.9	SL	1st CUT WHITE
2323	2126	8.8	4450	6.3	SL	2nd CUT WHITE
2159	1911	7.9	4071	6.4	SL	3rd CUT WHITE

Figure 12



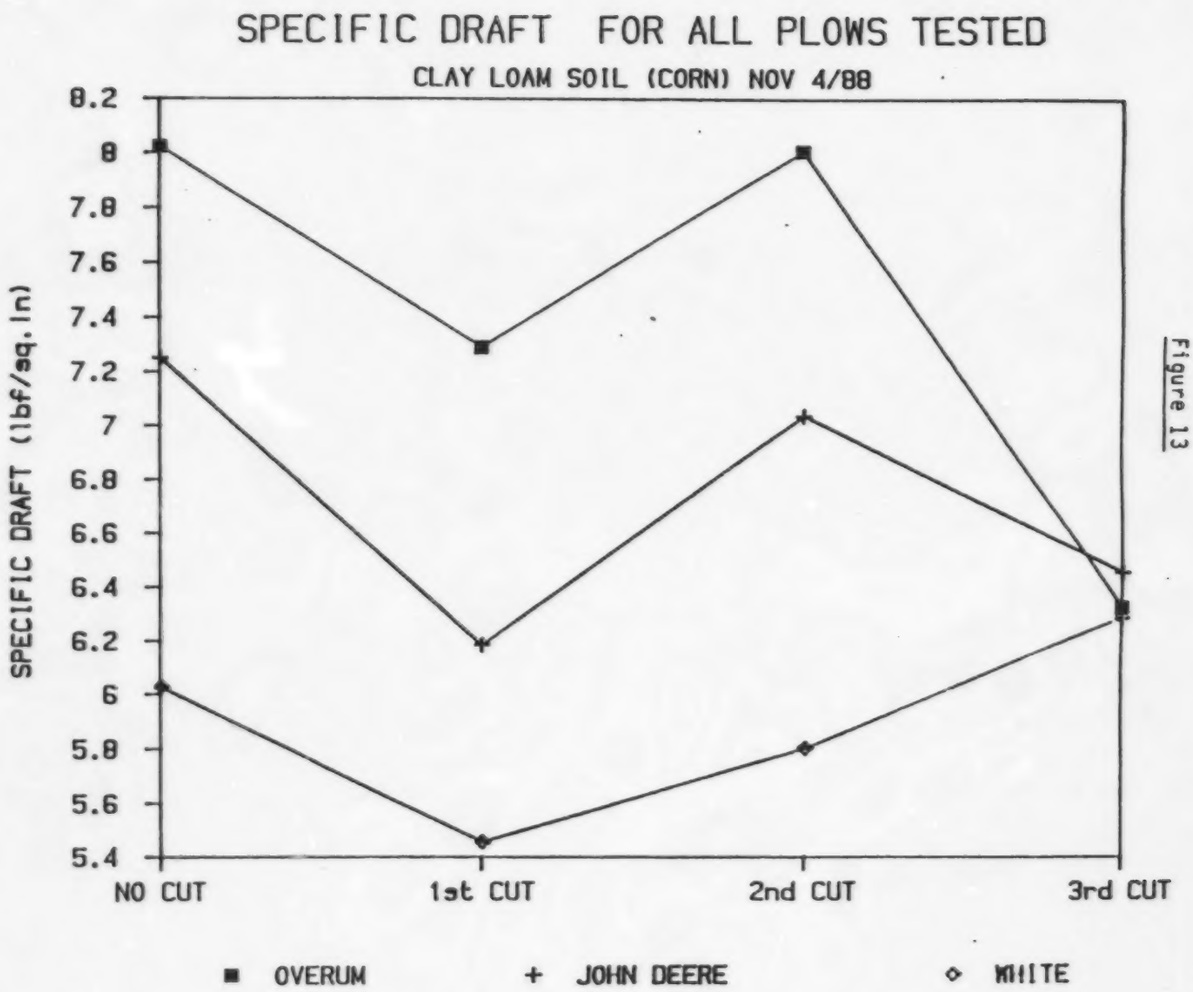


Figure 13

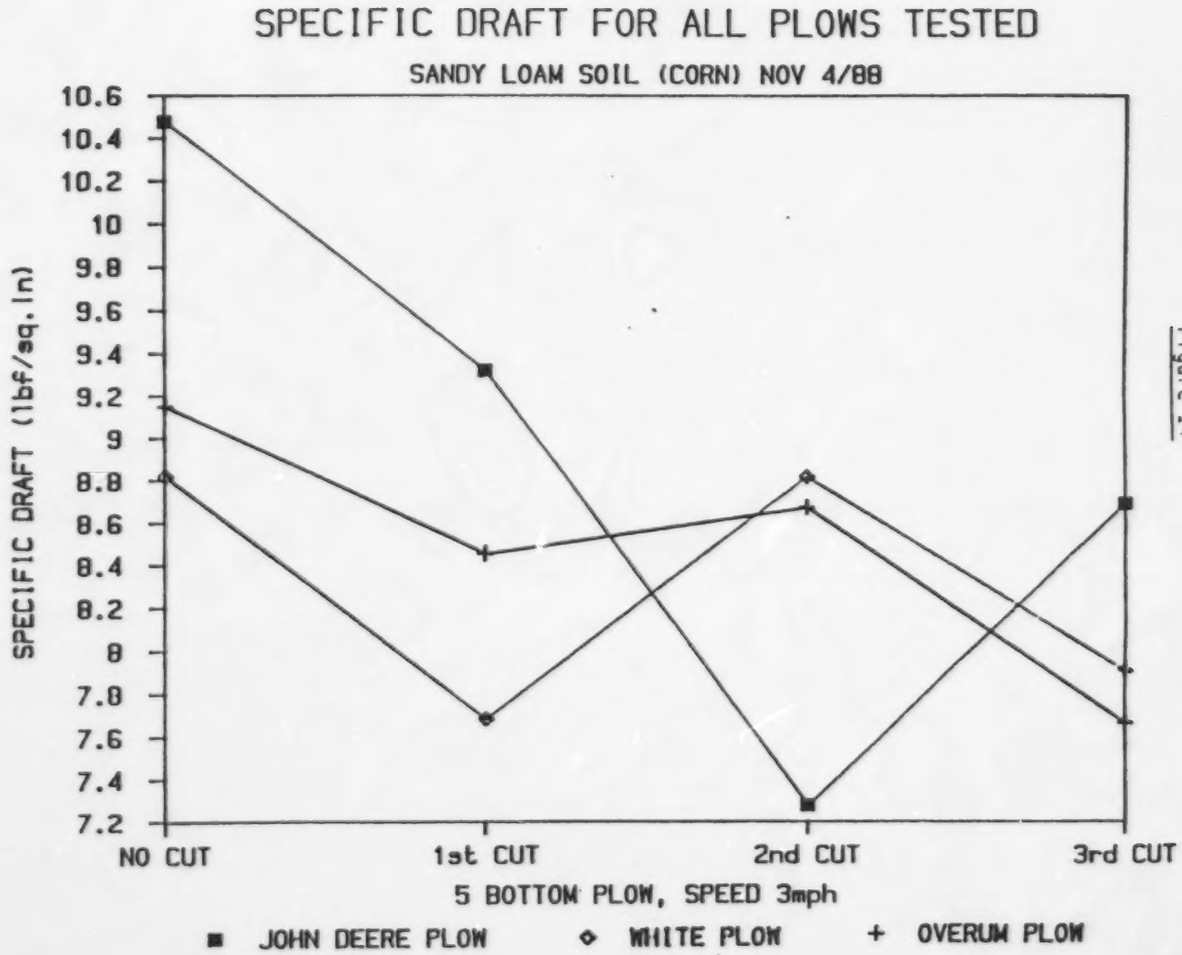


Figure 14

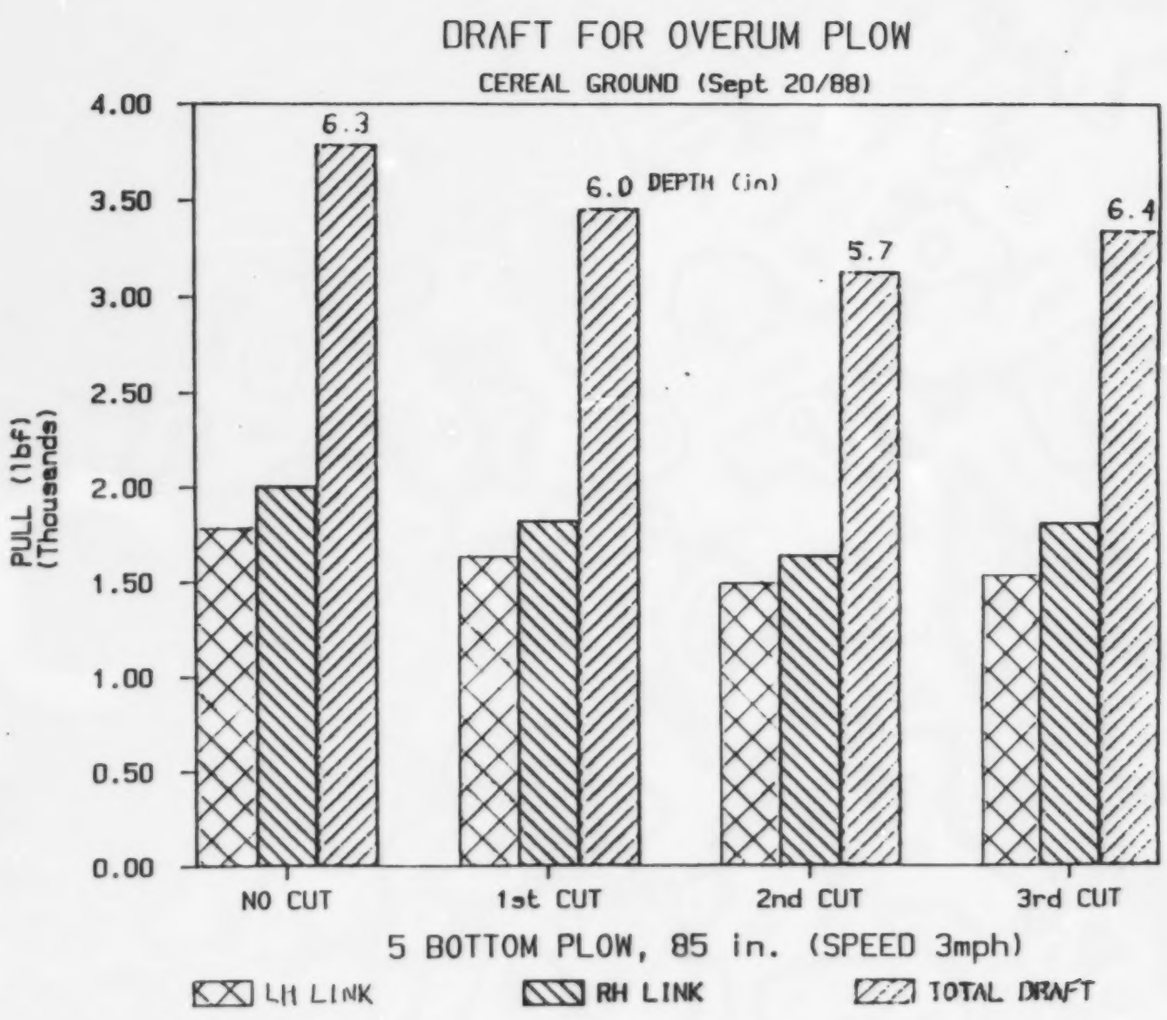


Figure 15

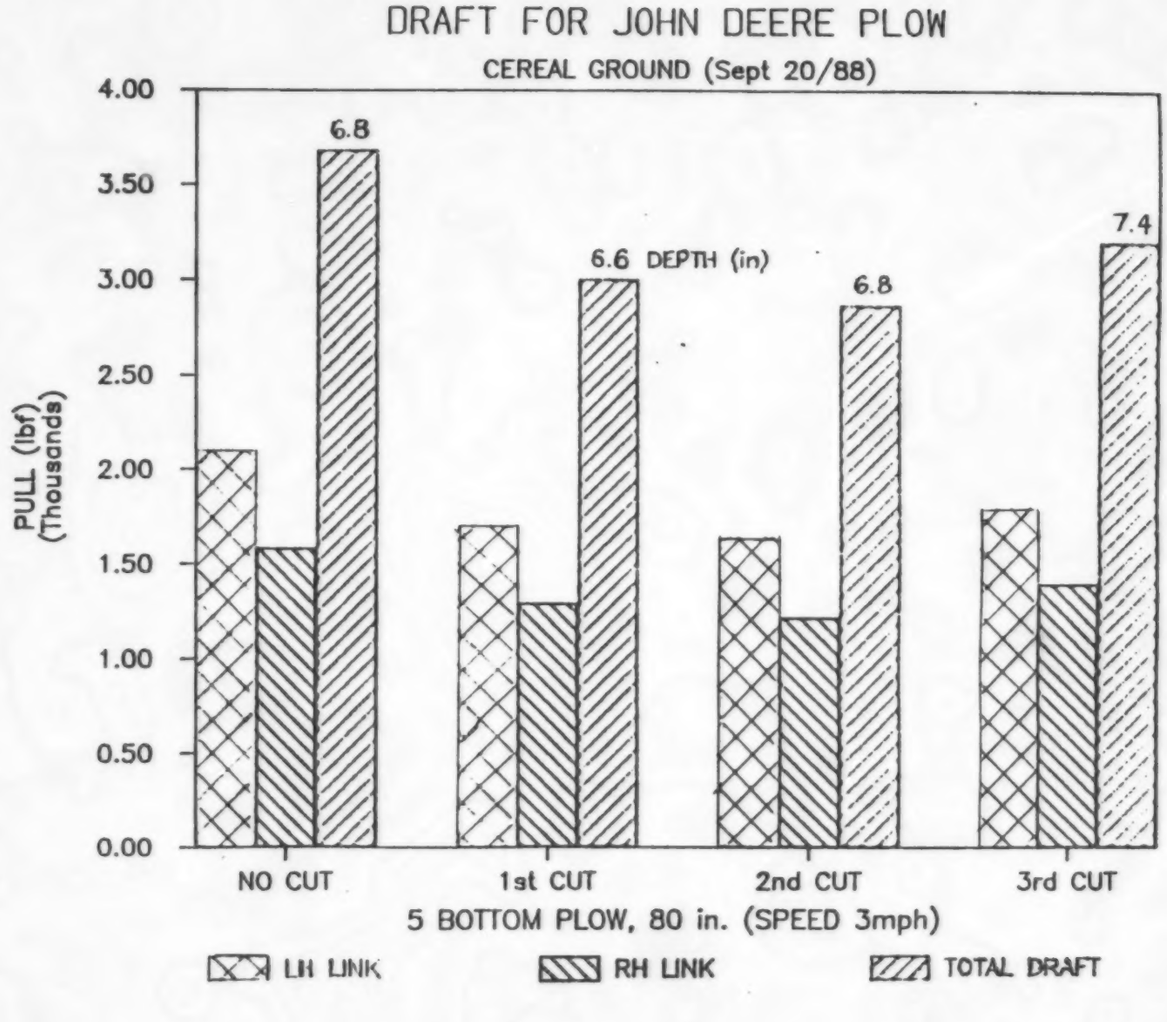
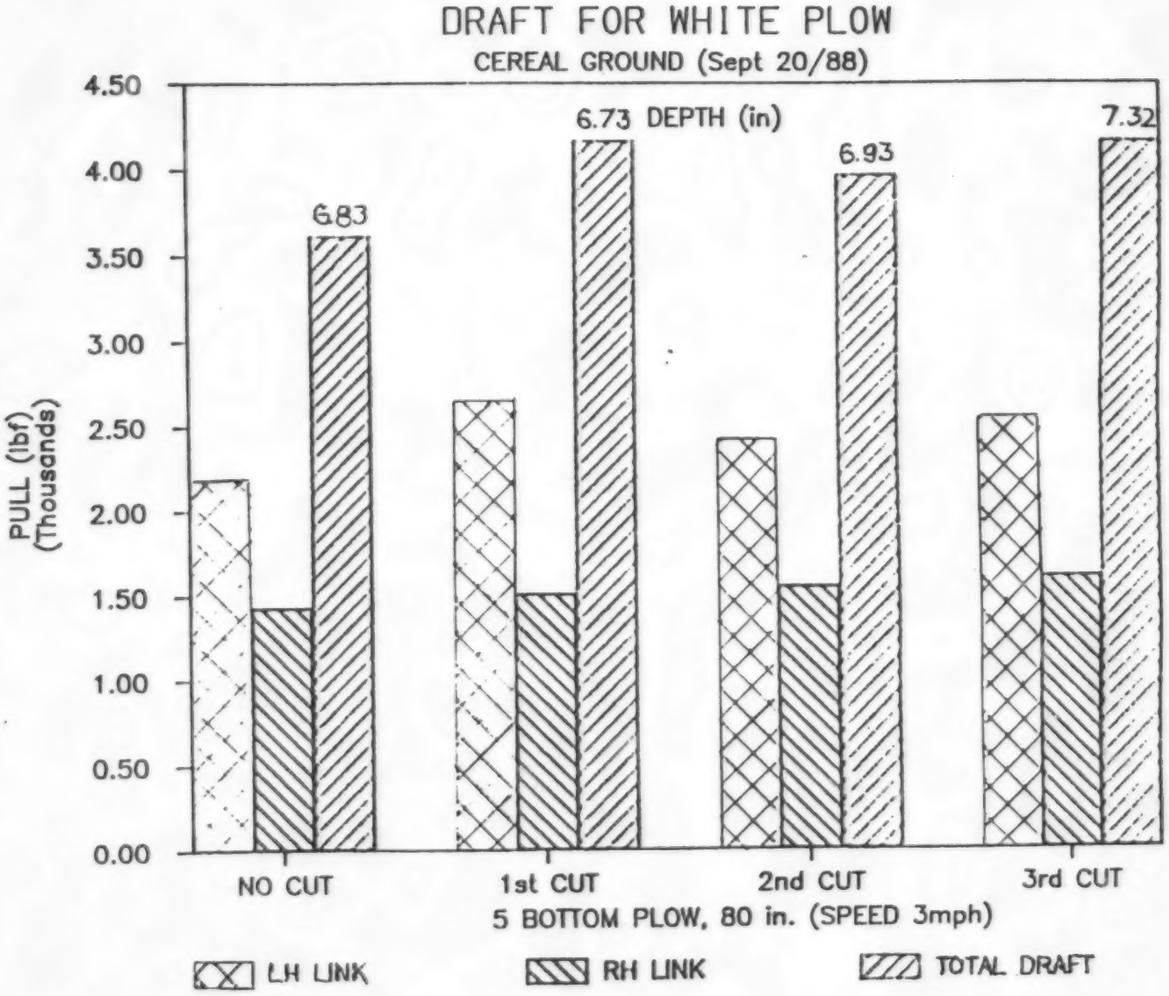


Figure 16



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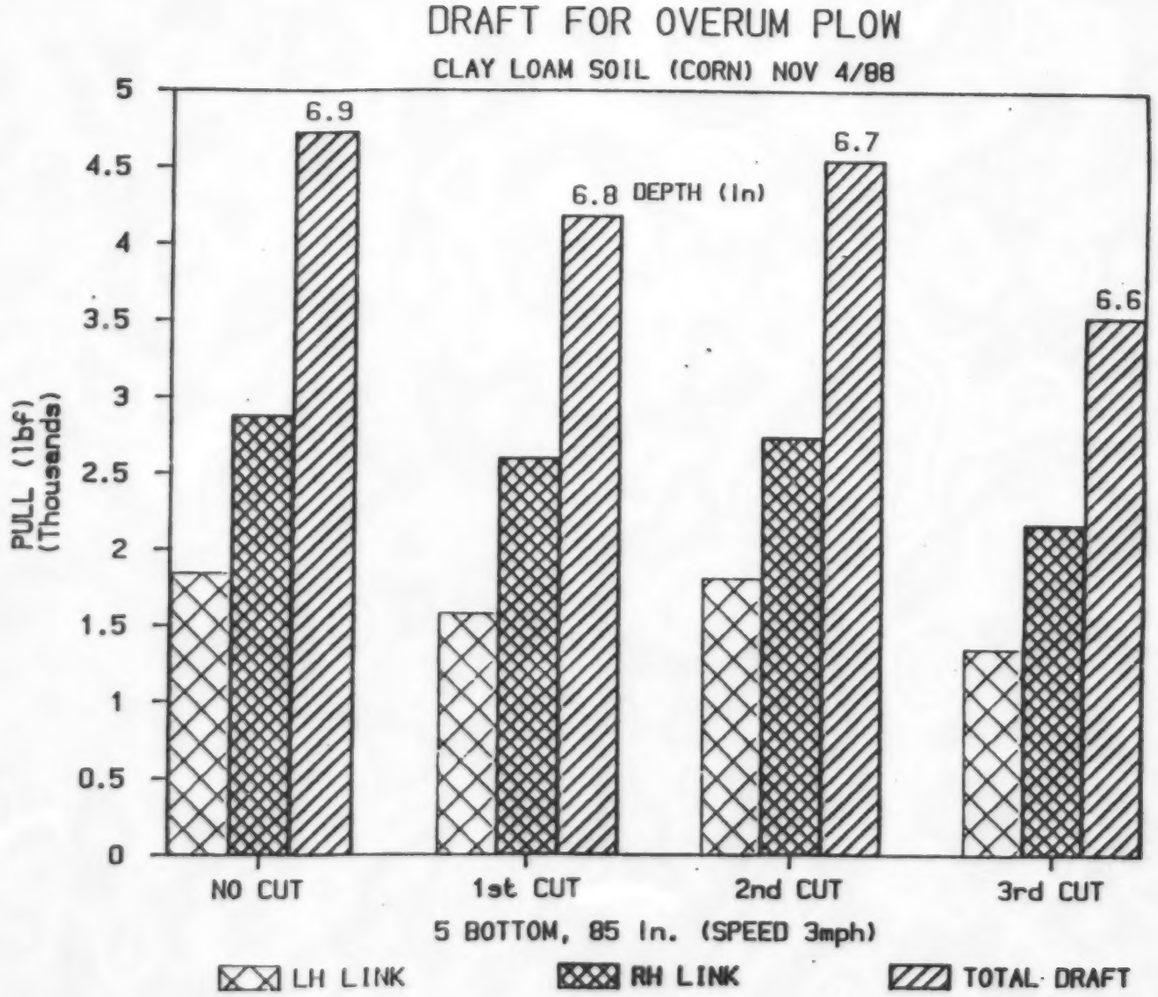
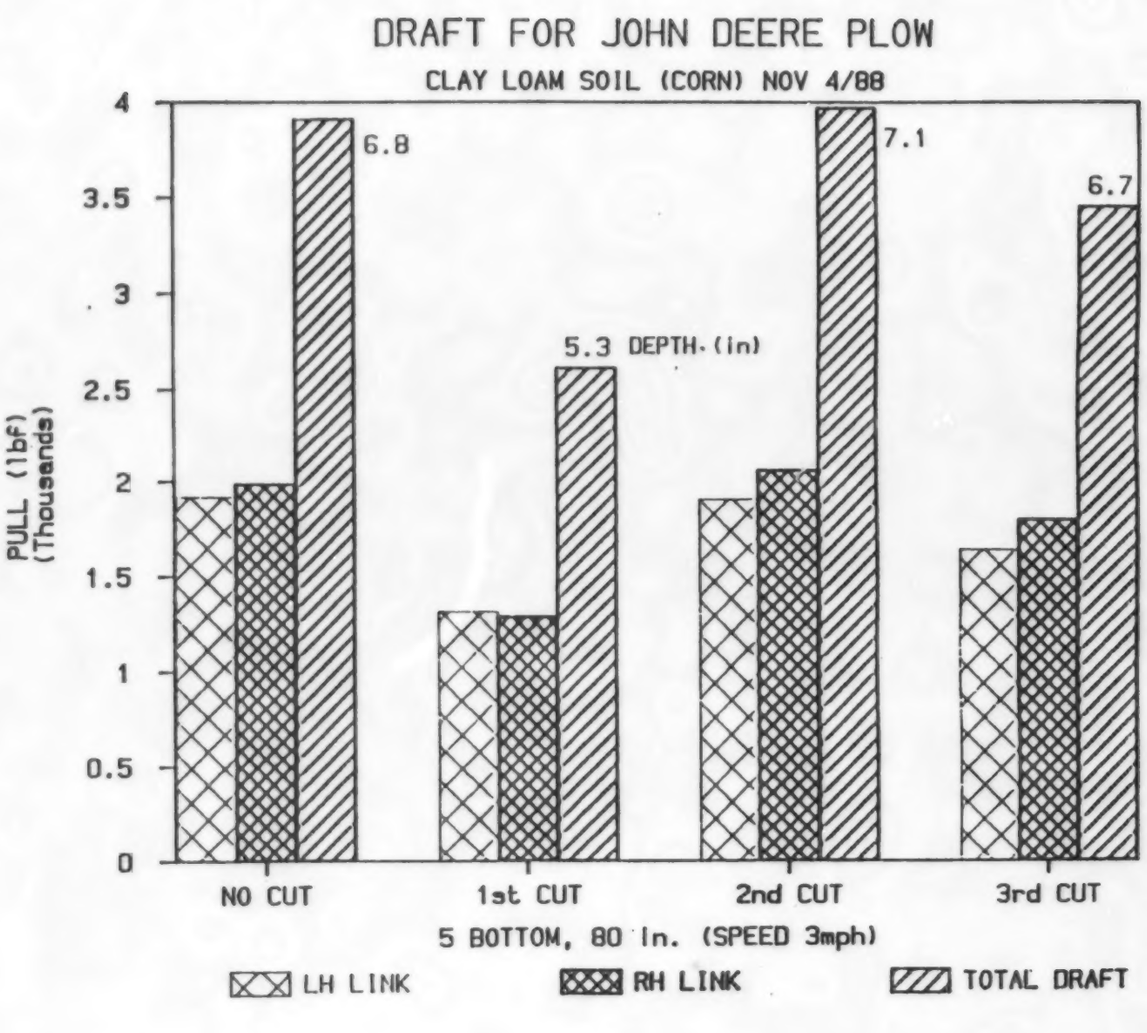


Figure 18



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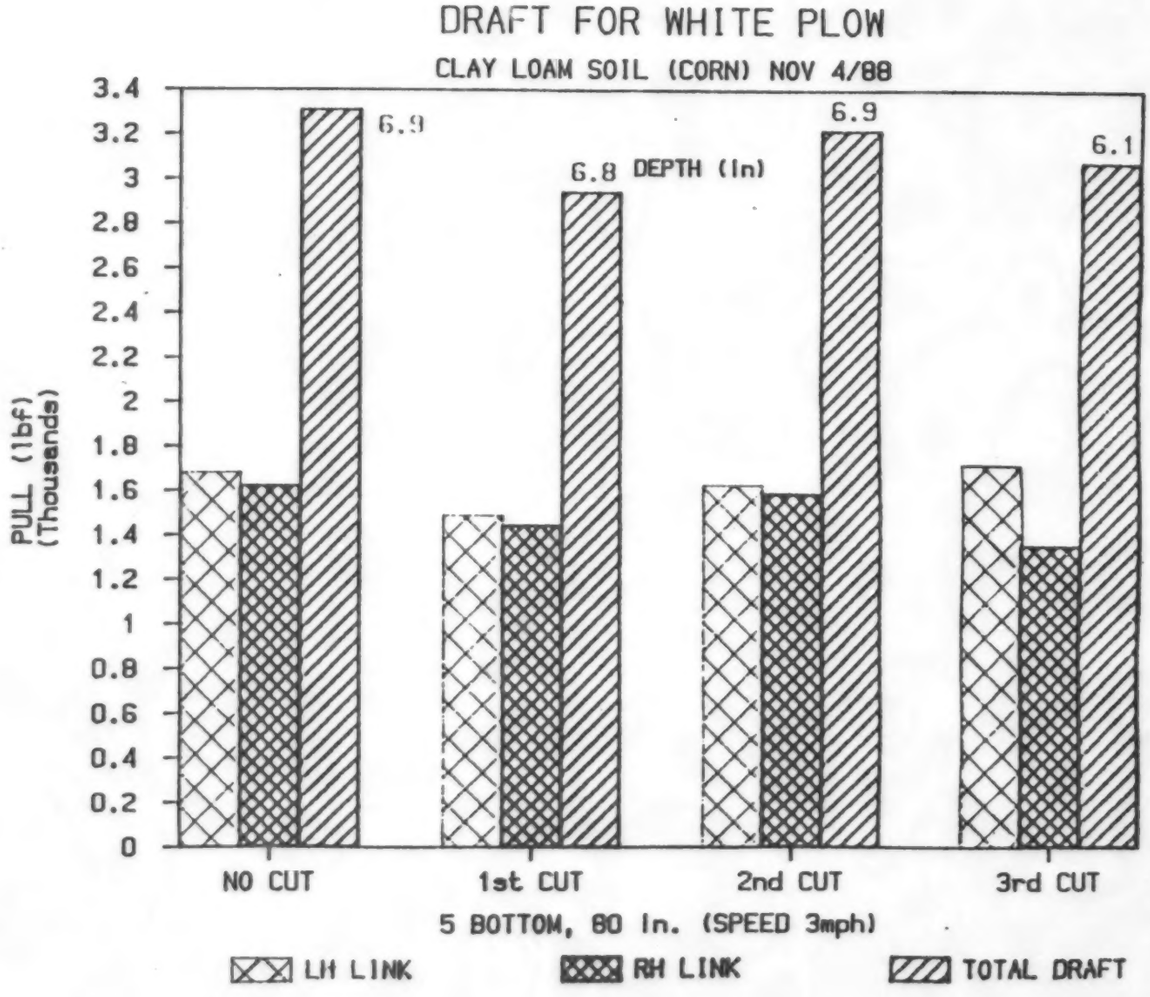

Figure 20

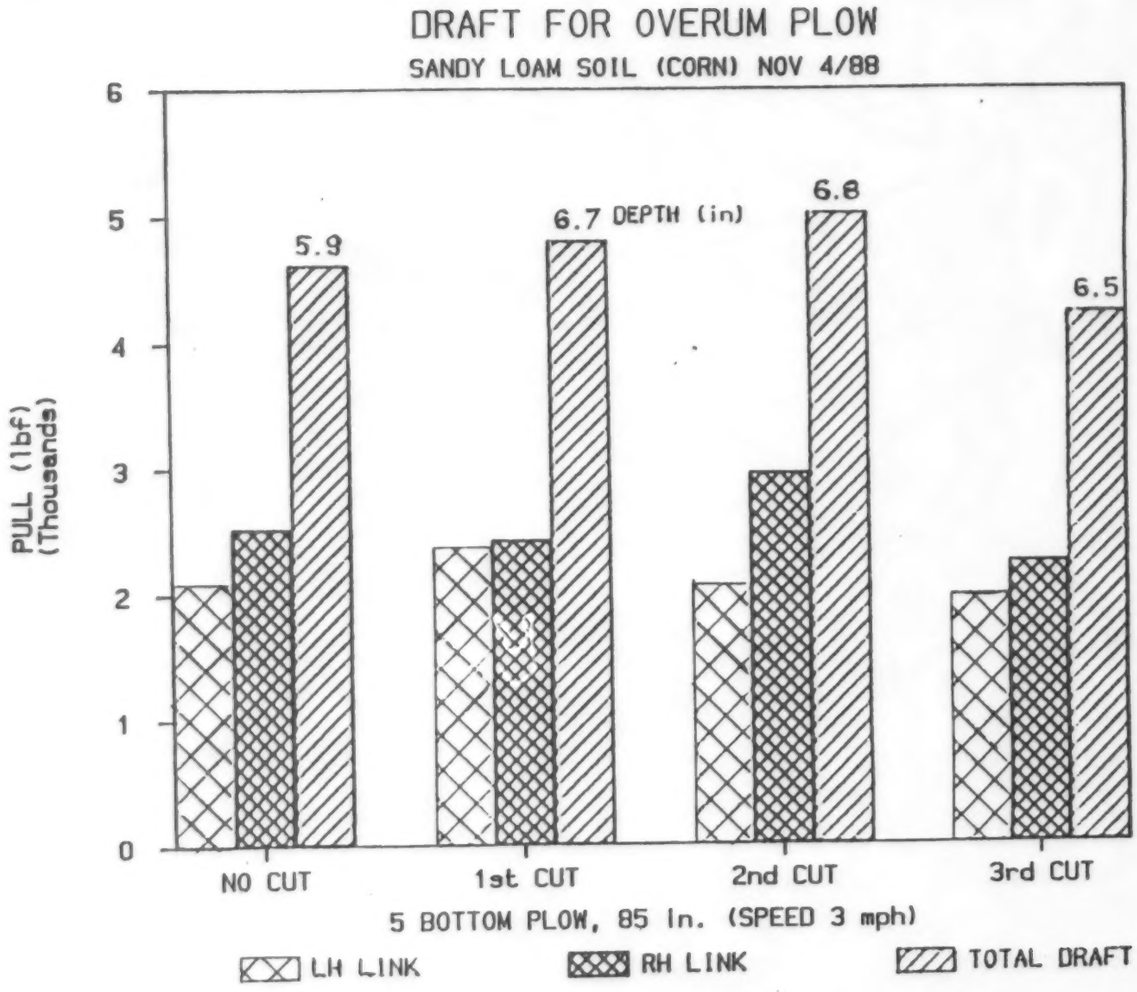

Figure 21

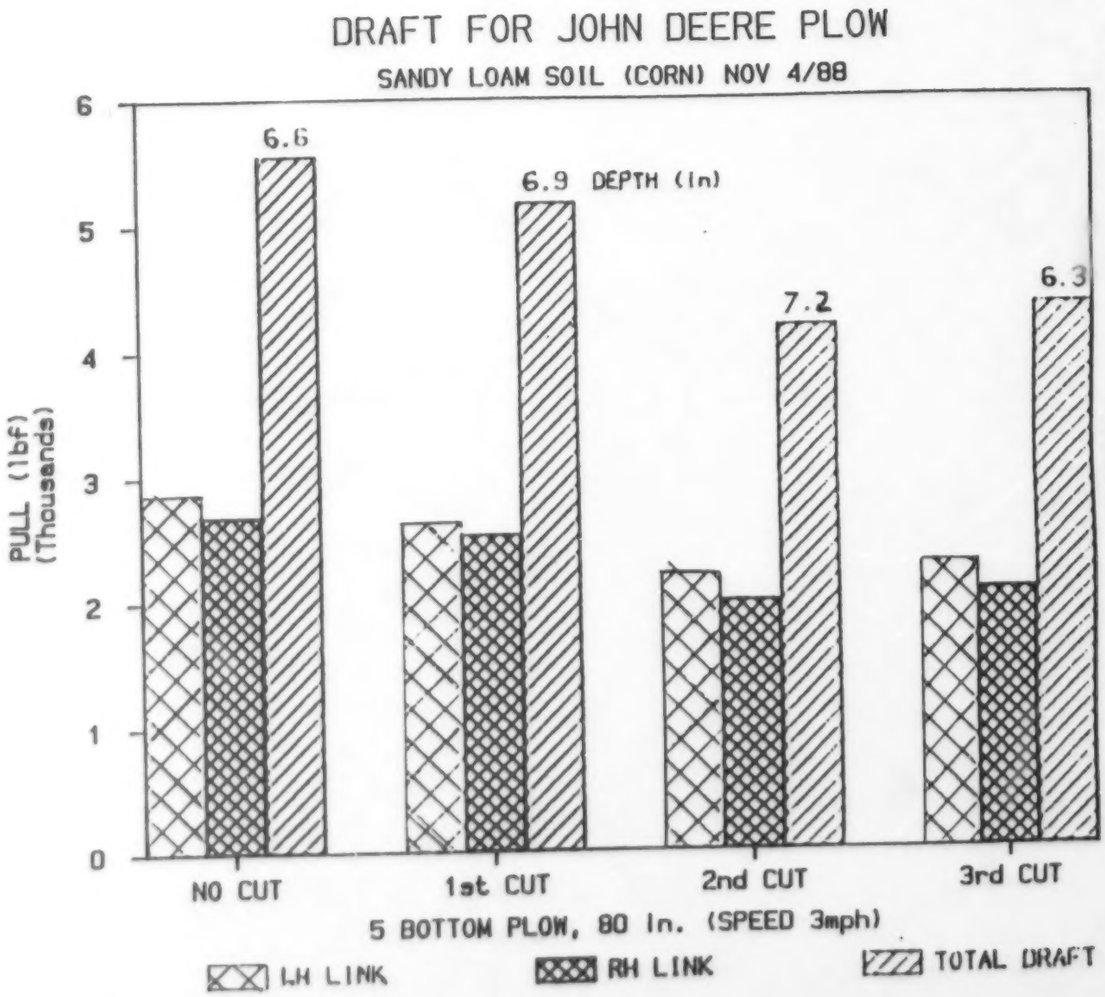

Figure 22

Figure 23

DRAFT FOR WHITE PLOW
SANDY LOAM SOIL (CORN) NOV 4/88
6.9 DEPTH (in)
6.9
6.3
6.4
PULL (lbf)
(Thousands)
5
4
3
2
1
0
NO CUT
1st CUT
2nd CUT
3rd CUT
5 BOTTOM PLOW, 80 In. (SPEED 3 mph)
LH LINK
RH LINK
TOTAL DRAFT

APPENDIX A

Field Data Collected

[illegible] TESTS ON DEPEAL SPRING

	PULL ON RH LINK (lbs)																PULL ON LH LINK (lbs)		ACTUAL TOTAL PULL (lbs)
[illegible] 412		plot 412																	
[illegible] 143 165 161 174	1526	12	14	16	17	19	22	21	23	26	21	19	21	18	24	20	1953		2977
0 155 168 166 172 244	1868	23	36	27	20	26	22	26	27	26	22	16	17				2400		3600
[illegible] 253 242 205 288 197	2238	25	23	28	32	28	31	24	37	21	25	36	33	33	38		2957		4445
																		AVG PULL	3674
ot 314		plot 314																	
1 134 142 176 176 181 165	1564	18	16	20	23	21	17	18	21	23	26	22	24	22			2085		3122
[illegible] 122 101 131 152 121	1317	22	13	16	17	16	22	16	21	17							1778		2647
[illegible] 191 244 379 231 238	2350	17	19	20	25	22	30	29	34	44	47	50	35	37	40		3200		4748
																		AVG PULL	3506
[illegible] 221		plot 221																	
[illegible] 170 140 231 208 214	1813	20	17	27	24	29	30	24	27	28	23	25					2491		3662
[illegible] 145 120 201 173	1520	15	18	19	17	23	25	22	21	24							2044		3049
0 200 215 223 235	2126	24	25	24	26	24	29	26	29	34							2678		4110
																		AVG PULL	3614
[illegible] 121		plot 121																	
7 161 177 168 149 168	1650	15	17	18	19	16	15	18	20	19	20	19					1782		2936
2 200 183 220 221	2012	23	25	27	26	24	28	29	27	30	31	35					2773		4093
[illegible] 204 259 231 307 229	2292	34	31	35	29	33	36	29	33	36							3289		4774
																		AVG PULL	3934
ot 413		plot 413																	
[illegible] 115 120 150 163 176 142	1387	15	16	20	17	18	17	18	20	22	24						1870		2786
[illegible] 145 151 175 195 175	1566	19	25	18	20	21	26	27	28	22	29	30					2427		3418
6 92 105 170 154	1218	12	15	15	14	16	12	16	14	15	16	17					1473		2302
																		AVG PULL	2836
[illegible] 311		plot 311																	
[illegible] 176 131 156 159	1516	19	16	20	21	25	20	21	19	18	21	23					2045		3047
3 140 176 155 199 186 174	1594	29	22	26	30	21	19	26	22	25	22	24	19	21			2285		3318
[illegible] 230 216 169 167 219	1885	23	25	30	28	26	25	27	25	27	26						2620		3854
																		AVG PULL	3406
[illegible] 222		plot 222																	
7 190 141 177 125 174	1573	14	11	13	15	17	16	15	22	16	17						1560		2681
[illegible] 141 123 144 150	1460	15	21	21	19	18	17	18	15	17	18	18					1791		2751
[illegible] 138 146 150 110	1378	15	18	19	21	18	16	19	20								1825		2740
																		AVG PULL	2724
[illegible] 123		plot 123																	
[illegible] 108 125 119 120 139 125	1229	17	15	16	17	16	17	18	15								1639		2452
[illegible] 220 140 177 159 144 145	1611	17	23	23	24	25	21	24	25	24	26						2340		3580
3 174 140 180 200	1714	21	16	21	23	22	24	19	20	21							2078		3244
																		AVG PULL	3025
[illegible] 414		plot 414																	
[illegible] 125 104 96 138	1154	13	15	16	14	13	15	17	17	18	19						1570		2330
[illegible] 172 167 145 144 185	1628	22	23	22	23	24	23	21	22	27	24						2310		3389
[illegible] 168 164 146 167	1584	17	19	21	20	19	24	24	21	22	21	21					2082		3145
																		AVG PULL	2948
ot 313		plot 313																	
[illegible] 171 200 233 250 272	2123	24	27	37	32	37	37	36	26								3238		4588
[illegible] 177 144 184 188 178	1682	22	16	20	21	18	30	22	26	31							2322		3428
[illegible] 118 165 147 202 151	1563	14	15	18	25	26	28	24	18								2100		3134
																		AVG PULL	3716

		PULL DA			ACTUAL
		RN LINE		..H LINE	TOTAL PULL
.ot 224	plot 224				
84 92 83 90 120 112	9 9 10 10 10 10 11 14 12 13	937		1080	1726
161 120 154 163	17 18 19 19 16 19 20 20 24 22	1498		1940	2941
116 135 134 172	15 19 16 19 18 20 17 20 19 24 26 27	1332		2000	2851
			AVG PULL		2506
t 124	plot 124				
95 76 93 89 97 99 88	11 11 9 10 11 12 10 13 10 11	878		1080	1675
08 102 121 145 170 141	13 13 14 14 13 15 16 20 22	1312		1556	2453
2 142 144 135 156 147	16 19 18 20 17 18 16 18 20	1410		1500	2746
			AVG PULL		2291
t 411	plot 411				
8 149 99 122	11 11 11 13 10 17 17 15 14 15 17	1170		1373	2175
151 122 140	16 20 21 17 16 18 17 16 19 16 17	1343		1755	2650
145 144 236 224 182 162 157	25 22 34 31 28 33 23 24 17	1741		2633	3742
			AVG PULL		2856
pt 312	plot 312				
136 150 214 250 288	26 24 27 28 27 32 33 35 33	1940		2944	4179
216 198 190 201	25 26 27 25 28 29 28 25 28	1974		2678	3980
4 164 177 150 150	18 20 21 26 25 25 26 21 19 20	1530		2210	3200
			AVG PULL		3786
t 223	plot 223				
0 168 192 222 240 224	14 17 23 21 23 24 27 26 25	1993		2222	3606
8 157 176 200 213 220	21 20 23 20 26 37 29 30 29 28	1890		2630	3867
115 119 102 117 103 110	12 14 13 11 13 10 15 10 12 11	1154		1190	2006
			AVG PULL		3160
lot 122	plot 122				
125 147 173 169 200 172	14 17 16 20 22 20 18 19 22 22	1606		1910	3008
163 175 182 192 200	17 18 17 17 21 21 21 22 22 23	1787		2000	3239
146 156 161 179	14 15 18 16 17 20 20 17 18 17	1492		1720	2748
			AVG PULL		2998
t 424	plot 424				
204 234 225	22 19 23 30 23 31 32 33 30 32	2090		2750	4141
2 213 120 146 160 158	20 29 32 21 22 29 28 29	1es7		1es3	3704
2 181 198 223	25 27 22 24 25 29 26 22	1960		2500	3730
			AVG PULL		3858
t 333	plot 333				
9 148 188 205 210 174	16 17 22 29 29 27 21 25 24 25	1725		2240	3476
165 201 215 170	24 25 33 36 25 26 29 28	1808		2825	3964
153 124 122 143 150	19 20 17 13 15 17 19	1492		1686	2719
			AVG PULL		3386
lot 211	plot 211				
167 142 102 150	27 29 21 24 30 22 20 21 19 19	1550		2210	3217
148 150 160	24 28 22 26 20 22 25 25 21 22	1505		2460	3592
4 166 216 196 156	23 28 30 35 36 33 32 29 3e	1720		2100	4124
			AVG PULL		3577
t 122	plot 122				
179 202 182 149 158	24 25 26 30 27 34 26 22 19 21	1798		2380	3751
153 122 144 182	25 28 23 21 22 23 27 21 27	1454		2489	3373
190 142 188 178	28 29 27 26 31 30 21 2e 28	1536		2389	3762
			AVG PULL		3629

	PULL ON A- LINE										PULL ON A- LINE	ACTUAL TOTAL PULL
ot 423		plot 423										
173 142 182 196 215	1698	25	34	33	29	25	28	24	28		2825	3870
142 159 202	1603	27	23	29	30	24	23	27	28	27	2644	3633
4 188 160 196 210	1736	23	31	34	32	35	43	31	29		3225	4244
											AVG PULL	3916
332		plot 332										
168 192 208 259	2016	37	35	32	29	32	37	30	38	36	3400	4633
3 188 176 250	1968	32	36	30	36	37	40	31	37	36	3500	4677
140 123 172 156	1542	33	35	42	41	34	26	30	32	34	3411	4237
											AVG PULL	4516
ot 212		plot 212										
5 177 197 184 152 176	1785	33	33	36	34	33	34	31	32	29	3278	4331
185 198 162 201	1798	34	35	36	28	34	33	30	33		3288	4351
144 169 175	1548	30	33	25	25	26	36	30	29	29	2922	3824
											AVG PULL	4169
133		plot 133										
168 149 152	1490	21	18	23	20	27	18	20	19	24	2111	3081
209 235 158	1975	30	32	30	36	33	32	36	30		3238	4459
4 196 220 235 183	2036	30	35	42	35	32	27	33	34		3350	4608
											AVG PULL	4049
422		plot 422										
2 180 244 216 206	2016	32	27	36	34	33	34	30	28		3175	4441
216 182 251 205	1962	24	25	28	27	34	27	30	33	34	2950	4202
146 206 240 182 201	1915	28	33	32	33	32	33	31			3171	4351
											AVG PULL	4332
ot 334		plot 334										
180 16[illegible] 210 204 140 170 182	1755	33	28	24	25	29	26	22	27	25	2656	3775
149 163 204 202 233 140	1790	21	26	26	32	32	33	31	37	35	3072	4184
4 127 173 152 162	1516	24	16	20	21	24	27	26	21	30	24	2330	3290
											AVG PULL	3749
213		plot 213										
184 176 151 167	1684	24	22	25	24	25	21	24	25	27	2411	3486
6 173 199 156 185 189	1830	26	27	25	29	25	25	2[illegible]	25	2[illegible]	2[illegible]9	3857
129 126 132 163 152	1378	19	18	19	18	20	21	20	23	19	18	1950	2847
											AVG PULL	3390
ot 131		plot 131										
2 206 175 198 170	1882	26	30	37	34	29	27	34	32	40	3211	4737
198 224 185 205 220	2007	29	30	31	33	35	29	32	31	33	3144	4407
191 217 189 204	2014	33	35	33	31	29	29	27	36	27	3111	4385
											AVG PULL	4383
421		plot 421										
188 187 206 181	1798	29	28	30	29	30	31	32	32	31	28	3[illegible]6	4[illegible]8
223 167 208 214	2008	26	32	31	38	40	35	28	30	30	30	3[illegible]1	4455
188 176 190 143	1814	33	31	32	31	29	33	32	31	32		3[illegible]a	4[illegible]1
											AVG PULL	4271
331		plot 331										
159 156 177 207	1836	31	29	27	27	26	24	26	24	23	26	2[illegible]1	3[illegible]12
201 182 196 211 234	1945	28	28	30	28	32	30	29	28	33	28	2[illegible]70	4[illegible]05
225 192 189 [illegible]	1950	28	30	36	29	28	29	30	29	30	29	2[illegible]93	4[illegible]72
											AVG PULL	4[illegible]71

	PULL ON RH LINK		PULL ON LH LINK	ACTUAL TOTAL PULL
ot 214		plot 214		
162 184 182 156 186	1582	28 25 24 27 23 25 22 32 27	2589	3568
191 189 216 169 200	1960	29 30 35 33 32 31 38 33 32 34	3270	4423
0 211 167 170 193	1842	29 23 24 27 31 29 27 24 27	2678	3867
			AVG PULL	3953
134		plot 134		
239 199 187 205	1996	31 34 29 42 31 29 28 31 36	3233	4474
5 215 224 217 205 198	2090	33 32 34 31 28 30 33 31 34	3178	4507
163 206 185 198	1834	27 34 32 28 24 30 31 28 30	2933	4078
			AVG PULL	4353
ot 431 (Ad)		plot 431 (Ad)		
179 192 158 203 213	1882	14 18 16 14 16 13 15 16 18 18	1580	2961
214 189 247 226 268	2220	22 23 22 24 22 23 22 21 24 22	2250	3824
334 247 281 299	3030	33 33 30 25 26 20 24 21 23 25 22 23	2542	4767
			AVG PULL	3851
323		plot 323		
207 200 198 207	1998	18 17 22 19 16 15 13 15 16 15 15 14	1625	3099
251 248 263 275 251	2625	30 27 28 23 22 21 22 23 21 25	2420	4316
5 268 239 273 261 248	2557	26 26 21 24 25 21 24 23 27 23	2390	4232
			AVG PULL	3882
234		plot 234		
204 151 220 202 187 145	1840	18 14 12 14 16 18 20 19 17 16 17	1645	2982
248 288 247 287 279	2688	21 19 22 23 22 23 27 23 20 21 23 24	2233	4216
289 258 263 270 205	2578	24 24 25 25 26 22 20 22 21 25 22	2327	4197
			AVG PULL	3796
ot 111		plot 111		
171 159 190 185	1848	17 17 15 16 13 14 15 13 14 15 14 12	1458	2829
240 238 225 231 206	2313	21 19 21 22 22 21 19 21 22 22 22 23 24	2146	3815
304 248 235	2565	22 21 23 24 25 23 25 25 24 25	2376	4222
			AVG PULL	3622
431		plot 431 (Ad)		
148 163 155 150	1520	14 15 13 14 15 14 13 13 15 14	1380	2481
180 200 210 224 242	2178	18 19 20 22 23 24 22 18 19	2078	3638
220 237 222 215 195	2135	17 19 20 19 21 19 20 17 18 17	1870	3425
			AVG PULL	3182
plot 321		plot 321		
178 155 154 144 166	1595	17 14 13 14 14 13 15 13 14	1411	2572
172 167 261 307 288 174	3333	23 23 21 23 24 25 26 25 25 23 24	2382	4033
275 295 303 268 307	2860	23 25 26 27 25 28 25 27 23 25	2540	4620
			AVG PULL	3742
231		plot 231		
164 177 163 171 159 166	1620	13 14 13 15 15 14 13 12 15 14	1380	2874
171 188 199 200 212 252 178	1979	18 16 17 18 17 15 16 15 17 18	1730	3173
267 260 234 250	2470	19 20 22 21 22 26 24 22 21 19 21	2155	3956
			AVG PULL	3234
112		plot 112		
172 183 188 164	1688	14 13 13 12 13 15 12 13 15 14	1340	2865
264 259 248	2618	21 20 26 26 20 27 24 25 23 24 23	2355	4251
292 282 271	2820	18 18 19 21 23 24 22 26 22 27 24	2236	4188
			AVG PULL	3657

	PULL ON RH LINK		PULL ON LH LINK	ACTUAL TOTAL PULL
t 434		plot 434		
112 134 155 120 140 150 132 142	1318	14 14 15 16 15 14 13 15 17 14	.470	2385
210 246 258 261 187	2268	27 22 25 29 26 25	25e7	4136
259 294 274 225	2552	24 26 29 26 30 24 21 22 25	2522	4341
			AVG PULL	3621
t 324		plot 324		
122 134 151 143 140 150	1440	14 13 14 12 13 11 13 17 11 14 13	1318	2360
192 203 223 200 202	1987	15 16 19 20 19 21 18 15 14 19	1790	3271
204 212 229 248 238	2210	16 18 19 19 20 22 21 19 21 22	1970	3576
			AVG PULL	3056
ot 232		plot 232		
160 162 208 178 159 180	1693	12 13 14 14 15 14 13 12 13 12	1320	2577
145 196 164 152	1668	16 18 14 13 11 12 12 12 13 14	1350	2582
218 190 203	2035	18 21 22 16 17 17 16 17 20 17	1810	3289
			AVG PULL	2816
t 113		plot 113		
170 155 168 152 171	1592	13 14 10 12 11 12 13 13 12 11 13 12	1217	2403
213 226 235 224 210	2217	19 16 19 20 21 17 21 20 18 19 19 20	1908	3529
138 190 258 254 227	2013	12 11 11 12 14 19 21 24 24	1644	3129
			AVG PULL	3020
t 433		plot 433		
161 205 214 230 189	1930	16 18 17 20 17 18 17 18 17 20	1780	3174
171 185 210 175 234 206	1950	17 16 15 16 18 17 18 21 16 21 18	1755	3169
175 190 202 174 160	1772	13 13 14 16 15 16 14 13 14 15	1430	2739
			AVG PULL	3027
t 322		plot 322		
240 207 253 211 224	2225	24 21 18 16 16 21 20 19 18 20 21	1945	3271
194 210 202 216 184 185 213	2003	17 19 16 19 16 17 16 18 17	1659	3186
282 210 209 202 199	2158	22 19 22 19 18 19 21 18 16 20	1940	3506
			AVG PULL	3421
t 233		plot 233		
211 280 273 230 240	2467	20 17 21 21 23 22 21 20 17 19 20	2006	3826
176 218 240 227	2182	21 13 15 16 19 18 20 19 17 18	1760	3372
281 212 220 227	2126	15 18 22 23 15 17 16 16 19 21	1840	3393
			AVG PULL	3530
et 114		plot 114		
218 242 207 185	2034	17 17 16 16 15 17 14 13 14 16 14	1536	3054
302 254 191 222 235 277	2229	20 20 26 22 19 19 18 19 20 17 19 23	2008	3881
266 207 175 208	2000	13 14 19 16 20 17 22 21 20 18 16 18	1783	3237
			AVG PULL	3391

DRAFT TESTS AT HARROW
IN CLAY LOAM SOIL

PLOT #	DATE	AVG. READING LH LINK (LB)	AVG. READING RH LINK (LB)	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
123	3/11	2344	3810						
		2440	3844						
		2480	3944						
		AVG.= 2421	AVG.= 3799	2071	3250	5322	7.75	CL	NO CUT OVERUM
221	3/11	1292	2378						
		1792	2988						
		2018	3167						
		AVG.= 1701	AVG.= 2844	1455	2433	3888	6	CL	NO CUT OVERUM
332	3/11	2150	3529						
		2266	3475						
		2084	3775						
		AVG.= 2167	AVG.= 3593	1854	3074	4927	7	CL	NO CUT OVERUM
433	4/11	2100	2767						
		2682	3233						
		2326	3686						
		AVG.= 2369	AVG.= 3229	2027	2762	4789	7	CL	NO CUT OVERUM
121	3/11	995	2020						
		1850	3400						
		1988	3363						
		AVG.= 1611	AVG.= 2928	1378	2505	3883	6.75	CL	1st CUT OVERUM
223	3/11	1568	2911						
		2036	3067						
		1810	3144						
		AVG.= 1805	AVG.= 3041	1544	2601	4145	6.5	CL	1st CUT OVERUM
331	3/11	2168	3538						
		2314	4000						
		2290	3970						
		AVG.= 2257	AVG.= 3836	1931	3282	5213	7.25	CL	1st CUT OVERUM
432	4/11	1575	2100						
		1898	2513						
		1760	2417						
		AVG.= 1744	AVG.= 2343	1492	2005	3497	6.5	CL	1st CUT OVERUM
122	3/11	2234	3644						
		2380	3800						
		1746	3089						
		AVG.= 2120	AVG.= 3511	1814	3004	4817	7	CL	2nd CUT OVERUM
222	3/11	2484	3571						
		2152	3185						
		1844	3200						
		AVG.= 2160	AVG.= 3319	1848	2839	4687	6.75	CL	2nd CUT OVERUM
334	3/11	1686	3150						
		2958	3838						
		2484	3300						
		AVG.= 2369	AVG.= 3429	2027	2934	4961	7	CL	2nd CUT OVERUM
434	4/11	1562	2213						
		2014	2688						
		1950	2700						
		AVG.= 1842	AVG.= 2534	1576	2168	3743	6	CL	2nd CUT OVERUM

PLOT #	DATE	AVG. READING LH LINK (LB)	AVG. READING RH LINK (LB)	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
124	3/11	1093	2069						
		1608	2470						
		1572	2750						
		AVG.= 1424	AVG.= 2430	1219	2079	3297	6	CL	3rd CUT OVERUM
224	3/11	1236	2425						
		1624	2522						
		1598	2600						
		AVG.= 1486	AVG.= 2516	1271	2152	3423	6	CL	3rd CUT OVERUM
333	3/11	1304	2510						
		2016	3344						
		1920	3222						
		AVG.= 1747	AVG.= 3025	1494	2588	4082	7.25	CL	3rd CUT OVERUM
431	4/11	1844	2313						
		1648	2133						
		1582	2129						
		AVG.= 1691	AVG.= 2192	1447	1875	3322	7	CL	3rd CUT OVERUM
114	3/11	1788	1955						
		2262	2360						
		2406	2790						
		AVG.= 2152	AVG.= 2368	1841	2026	3867	6.5	CL	NO CUT JD
232	3/11	1860	1800						
		2476	2378						
		2386	2356						
		AVG.= 2241	AVG.= 2178	1917	1863	3780	7	CL	NO CUT JD
322	3/11	2064	2122						
		2734	2650						
		2738	2657						
		AVG.= 2512	AVG.= 2476	2149	2119	4268	7	CL	NO CUT JD
421	4/11	1796	1850						
		2168	2222						
		2338	2767						
		AVG.= 2101	AVG.= 2280	1797	1950	3747	6.5	CL	NO CUT JD
112	3/11	2040	2080						
		2082	2338						
		2262	2433						
		AVG.= 2128	AVG.= 2284	1821	1954	3774	7	CL	1ST CUT JD
223	3/11	2028	2340						
		2334	2400						
		2336	2430						
		AVG.= 2233	AVG.= 2390	1910	2045	3955	7	CL	1ST CUT JD
321	3/11	2404	2433						
		2320	2422						
		2182	2344						
		AVG.= 2302	AVG.= 2400	1969	2053	4022	7	CL	1ST CUT JD
424	4/11	1816	1864						
		2482	2350						
		2300	2088						
		AVG.= 2199	AVG.= 2101	1882	1797	3679	7.25	CL	1ST CUT JD

DRAFT TEST ON CLAY LOAM SOIL

PLOT #	DATE	AVG. READING LH LINK (LB)	AVG. READING RH LINK (LB)	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
111	3/11	2160	2544						
		2098	2425						
		AVG.= 2129	AVG.= 2485	1821	2125	3947	7	CL	2nd CUT JD
231	3/11	2262	2444						
		1982	2356						
		2456	2538						
		AVG.= 2233	AVG.= 2446	1911	2093	4003	7	CL	2nd CUT JD
323	3/11	2490	2410						
		2246	2430						
		2404	2486						
		AVG.= 2380	AVG.= 2442	2036	2089	4125	7	CL	2nd CUT JD
423	4/11	2038	2078						
		2258	2313						
		2304	2410						
		AVG.= 2200	AVG.= 2267	1882	1939	3822	7.25	CL	2nd CUT JD
113	3/11	1394	1660						
		1676	1889						
		1930	2125						
		AVG.= 1667	AVG.= 1891	1426	1618	3044	6.75	CL	3rd CUT JD
234	3/11	1698	1850						
		2482	2470						
		2246	2570						
		AVG.= 2142	AVG.= 2297	1832	1965	3797	6.75	CL	3rd CUT JD
324	3/11	1850	2027						
		1890	2255						
		1948	2325						
		AVG.= 1896	AVG.= 2202	1622	1884	3506	7.25	CL	3rd CUT JD
422	4/11	1886	1791						
		2074	2167						
		2090	2178						
		AVG.= 2017	AVG.= 2045	1725	1750	3475	6	CL	3rd CUT JD

PLOT #	DATE	AVG. READING LH LINK (LB)	AVG. READING RH LINK (LB)	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
133	3/11	1536	1523						
		2482	2400						
		2120	1980						
		AVG.= 2046	AVG.= 1981	1750	1678	3428	7	CL	NO CUT WHITE
214	3/11	1794	1718						
		2246	2190						
		2528	2288						
		AVG.= 2189	AVG.= 2065	1873	1767	3640	7.5	CL	NO CUT WHITE
313	3/11	1572	1500						
		2356	1850						
		1756	1567						
		AVG.= 1895	AVG.= 1639	1621	1402	3023	6	CL	NO CUT WHITE
414	4/11	1537	1611						
		1828	2100						
		1928	2089						
		AVG.= 1764	AVG.= 1933	1509	1654	3163	7	CL	NO CUT WHITE
131	3/11	1512	1567						
		1774	1636						
		1990	1873						
		AVG.= 1759	AVG.= 1692	1505	1448	2952	6.5	CL	1st CUT WHITE
213	3/11	1968	1810						
		1740	1570						
		1794	1760						
		AVG.= 1834	AVG.= 1647	1569	1409	2978	6	CL	1st CUT WHITE
312	3/11	1868	1830						
		1462	1467						
		1522	1475						
		AVG.= 1617	AVG.= 1524	1384	1304	2687	6.5	CL	1st CUT WHITE
413	4/11	1858	2011						
		1662	1940						
		1664	1756						
		AVG.= 1795	AVG.= 1902	1535	1627	3163	8	CL	1st CUT WHITE

DRAFT TEST ON CLAY LOAM SOIL

PLOT #	DATE	AVG. READING LH LINK (LB)	AVG. READING RH LINK (LB)	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN)	SOIL TYPE	PLOW CUT/TYPE
113	3/11	1378	1457						
		1322	1508						
		1664	1608						
		AVG.= 1455	AVG.= 1524	1244	1304	2549	6.25	CL	2nd CUT WHITE
211	3/11	1578	1640						
		1784	1673						
		1974	2082						
		AVG.= 1779	AVG.= 1798	1522	1538	3060	7	CL	2nd CUT WHITE
311	3/11	2084	1917						
		1654	1633						
		AVG.= 1869	AVG.= 1775	1599	1519	3117	6.75	CL	2nd CUT WHITE
411	4/11	2136	2178						
		2722	2389						
		2720	2440						
		AVG.= 2526	AVG.= 2336	2161	1998	4159	7.75	CL	2nd CUT WHITE
132	3/11	1732	944						
		1947	1025						
		1702	1230						
		AVG.= 1794	AVG.= 1066	1534	912	2447	6	CL	3rd CUT WHITE
212	3/11	1660	1129						
		1926	1583						
		2310	1623						
		AVG.= 1965	AVG.= 1445	1681	1236	2918	6	CL	3rd CUT WHITE
314	3/11	1608	1308						
		2000	1773						
		1956	1614						
		AVG.= 1855	AVG.= 1565	1587	1339	2926	6.5	CL	3rd CUT WHITE
412	4/11	1974	1950						
		1966	1922						
		3378	3060						
		AVG.= 2439	AVG.= 2277	2087	1946	4033	6	CL	3rd CUT WHITE

DRAFT TEXT FOR REPORT
IN HARD COPY FILE

PLOT #	DATE	AVG. READING LB LINE	AVG. READING LBS PR LINE	ACTUAL PULL LB LINE	ACTUAL PULL LBS PR LINE	TOTAL PULL LBS	DEPTH INS	SOIL TYPE	FLOW CUT TYPE
122	2/11	1342	1800						
		1662	1730						
		AVG.= 1502	AVG.= 1765	1285	1510	2795	5	SL	NO CUT OVERUM
224	2/11	2012	2189						
		2586	2950						
		2512	2956						
		AVG.= 2370	AVG.= 2665	2028	2280	4308	6.5	SL	NO CUT OVERUM
322	4/11	2968	3450						
		2880	3617						
		2764	3725						
		AVG.= 2837	AVG.= 3597	2426	3078	5504	7	SL	NO CUT OVERUM
423	4/11	2764	3422						
		3330	4000						
		3134	3922						
		AVG.= 3076	AVG.= 3781	2632	3325	5867	7.25	SL	NO CUT OVERUM
121	2/11	2264	2340						
		4010	2100						
		3572	2230						
		AVG.= 3282	AVG.= 2223	2808	1902	4710	6	SL	1st CUT OVERUM
222	2/11	3328	1967						
		2770	2529						
		2800	2625						
		AVG.= 2966	AVG.= 2374	2537	2031	4569	6.25	SL	1st CUT OVERUM
324	4/11	2262	3375						
		2850	3650						
		2352	3863						
		AVG.= 2488	AVG.= 3629	2126	3105	5233	7.75	SL	1st CUT OVERUM
424	4/11	1956	2656						
		2392	3078						
		2814	3650						
		AVG.= 2387	AVG.= 3128	2042	2676	4718	6.75	SL	1st CUT OVERUM
124	2/11	1744	3483						
		1740	2650						
			2717						
		AVG.= 1742	AVG.= 2950	1490	2524	4014	7	SL	2nd CUT OVERUM
221	2/11	2178	3400						
		2600	3475						
		1717	3014						
		AVG.= 2165	AVG.= 3296	1852	2820	4672	6.5	SL	2nd CUT OVERUM
421	4/11	2452	3238						
		3184	3967						
		3134	3983						
		AVG.= 2917	AVG.= 3729	2495	3190	5686	7	SL	2nd CUT OVERUM
333	4/11	2006	2825						
		3416	4433						
		3084	4263						
		AVG.= 2835	AVG.= 3840	2426	3285	5711	6.75	SL	2nd CUT OVERUM

PLOT #	DATE	AVG. READING LH LINK LBS.	AVG. READING RH LINK LBS.	ACTUAL PULL LH LINK LBS.	ACTUAL PULL RH LINK LBS.	TOTAL PULL LBS.	DEPTH INS.	SOIL TYPE	PLOW CUT TYPE
123	2/11	1830	2080						
		1424	1870						
		2214	1922						
	AVG.=	1796	AVG.= 1957	1539	1674	3214	6	SL	2nd CUT OVERUM
222	2/11	2316	2689						
		2554	2400						
		2810	2175						
	AVG.=	2493	AVG.= 2421	2133	2671	4804	6.75	SL	2nd CUT OVERUM
422	4/11	2432	3063						
		2652	3050						
		2450	3100						
	AVG.=	2511	AVG.= 3071	2148	2627	4776	6.75	SL	2nd CUT OVERUM
231	4/11	2164	2789						
		2628	3125						
		2896	3233						
	AVG.=	2493	AVG.= 3049	2132	2608	4741	6.5	SL	2nd CUT OVERUM
113	2/11	3638	2913						
		2970	2580						
		3326	3300						
	AVG.=	3311	AVG.= 2931	2822	2507	5340	7.25	SL	NO CUT JD
221	2/11	4224	3717						
		3262	2613						
		3344	3033						
	AVG.=	3610	AVG.= 3121	3088	2670	5758	7.25	SL	NO CUT JD
311	4/11	2408	2822						
		2902	3033						
		2342	3183						
	AVG.=	2851	AVG.= 2939	2439	2515	4953	6	SL	NO CUT JD
421	4/11	2871	3300						
		4152	3400						
		3608	3550						
	AVG.=	3617	AVG.= 3583	3094	3066	6160	6	SL	NO CUT JD
111	2/11	3556	3100						
		2094	2244						
		2304	2200						
	AVG.=	2851	AVG.= 2515	2268	2151	4420	6.5	SL	1st CUT JD
224	2/11	2980	2850						
		2174	2063						
		2466	2830						
	AVG.=	2540	AVG.= 2581	2173	2208	4381	7.25	SL	1st CUT JD
312	4/11	3284	3256						
		3916	3513						
		2912	2838						
	AVG.=	3371	AVG.= 3202	2884	2740	5623	6.5	SL	1st CUT JD
433	4/11	3788	3750						
		3704	3436						
		3874	3427						
	AVG.=	3789	AVG.= 3538	3241	3026	6268	7.5	SL	1st CUT JD

[illegible] TEST ON SANDY LOAM SOIL

PLOT #	DATE	AVG. READING LH LINK (LB	AVG. READING RH LINK (LB	ACTUAL PULL LH LINK (LB)	ACTUAL PULL RH LINK (LB)	TOTAL PULL (LB)	DEPTH (IN	SOIL TYPE	PLOW OR TYPE
114	3/11	1736	1900						
		1881	1871						
		2090	1950						
	AVG.=	1902	AVG.= 1907	1627	1671	3298	6.5	SL	2nd CUT JD
223	3/11	2895	2300						
		2014	1833						
		2282	2187						
	AVG.=	2397	AVG.= 2106	2081	1801	3882	8.75	SL	2nd CUT JD
311	4/11	3008	2145						
		3802	3567						
		2528	2057						
	AVG.=	3212	AVG.= 2590	2748	2215	4963	7.75	SL	2nd CUT JD
434	4/11	2524	2380						
		3018	3000						
	AVG.=	2771	AVG.= 2690	2371	2301	4672	7.75	SL	2nd CUT JD
112	3/11	2742	2213						
	AVG.=	2742	AVG.= 2213	2346	1893	4239	6	SL	3rd CUT JD
222	3/11	2278	1989						
		1752	1627						
	AVG.=	2015	AVG.= 1808	1724	1547	3271	6	SL	3rd CUT JD
314	4/11	2566	2444						
		2460	2200						
	AVG.=	2513	AVG.= 2322	2150	1986	4136	6.25	SL	3rd CUT JD
422	4/11	3266	3125						
		3088	3300						
		3760	3567						
	AVG.=	3371	AVG.= 3331	2884	2849	5734	6.75	SL	3rd CUT JD
122	3/11	3168	3092						
		2172							
		2092	1838						
	AVG.=	2477	AVG.= 2465	2119	2109	4228	7.5	SL	NO CUT WHITE
214	3/11	3004	2425						
		3192	2554						
		2376	1850						
	AVG.=	2857	AVG.= 2276	2444	1947	4391	8.25	SL	NO CUT WHITE
323	4/11	3042	2625						
		3320	2950						
		3608	3114						
	AVG.=	3323	AVG.= 2863	2843	2449	5292	6.5	SL	NO CUT WHITE
414	4/11	3144	2563						
		3368	3386						
		3806	3586						
	AVG.=	3439	AVG.= 3178	2942	2719	5661	7.5	SL	NO CUT WHITE

PLOT #	DATE	A.S. READING LB/LINK	AVG.	RE-DRAW (LBS) LB/LINK	ACTUAL PULL LB/LINK (LBS)	ACTUAL PULL LB	TOTAL PULL (LBS)	DEPTH (IN)	SOIL TYPE	PLOW PLOT TYPE
132	2/11	2014		1764						
		AVG.= 2014	AVG.=	1764	1723	1509	3232	6	SL	1st CUT WHITE
217	2/11	2078		2242						
		2548		2500						
		2528		2228						
		AVG.= 2435	AVG.=	2322	2126	1987	4112	7	SL	1st CUT WHITE
322	4/11	2696		2567						
		2670		2922						
		3396		2820						
		AVG.= 2861	AVG.=	2770	2447	2769	4817	7	SL	1st CUT WHITE
412	4/11	3038		3000						
		2530		2575						
		2908		2600						
		AVG.= 2825	AVG.=	2725	2417	2331	4748	7.5	SL	1st CUT WHITE
131	2/11	1774		1743						
		1750		1762						
		2498		2472						
		AVG.= 2007	AVG.=	1992	1717	1704	3422	5.25	SL	2nd CUT WHITE
212	2/11	2738		2254						
		3780		3033						
		2268		1958						
		AVG.= 2929	AVG.=	2415	2505	2066	4572	7	SL	2nd CUT WHITE
324	4/11	2530		2203						
		3512		3244						
		2906		2558						
		AVG.= 2983	AVG.=	2678	2552	2291	4842	6.5	SL	2nd CUT WHITE
411	4/11	2698		2188						
		3026		2740						
		3208		3147						
		AVG.= 2944	AVG.=	2857	2519	2444	4963	6.5	SL	2nd CUT WHITE
134	2/11	1200		1070						
		1041		1279						
				936						
		AVG.= 1120	AVG.=	1062	958	908	1866	5.25	SL	3rd CUT WHITE
211	2/11	3048		2278						
		3336		2734						
		3480		2720						
		AVG.= 3288	AVG.=	2581	2284	2208	4992	6	SL	3rd CUT WHITE
321	4/11	2580		2244						
		2585		2906						
		AVG.= 2619	AVG.=	2426	2241	2075	4316	7.25	SL	3rd CUT WHITE
413	4/11	2892		2578						
		3276		3078						
		3142		2830						
		AVG.= 3103	AVG.=	2849	2655	2454	5109	7.25	SL	3rd CUT WHITE